SMATV/HEADENDS

GETTING ON ONE CABLE

ALL IN One Wire

Many people find it fascinating, perhaps even difficult to understand, how one small wire only slightly larger than a standard pencil in diameter can transport into their living room or bedroom dozens, indeed a hundred or more, totally seperate channels of television. After some 35 years of cable television or CATV, the mystery of how all of this works, and when working properly, works so well, mystifies many.

The 'secret' of cable television, whether the cable system serves two homes or two million homes, is really quite simple to understand. Each television channel has its own operating frequency. The same wire can carry an almost unlimited number of 'frequencies'. It is the job of the cable system designer to 'transmit' those seperate frequencies from the starting point (called **'headend'**) of the cable system in such a manner that any television receiver connected to the cable can in turn 'seperate' the frequencies so that only one, at a time, is processed by the TV set. This is not unlike the 3.7 to 4.2 GHz 'satellite band' which transmits, as a 'band of frequencies' as many as

24 seperate TV program channels. We have all learned that the individual TVRO receiver is 'tuned' through those channels so that only one at a time exists in the TVRO receiver, even if 24 went in.

There are two legal definations of 'cable' which concern us. As a companion series apprearing in **CSD**'s mid-month companion publication **CJR** is presently pointing out, there is one definition created by the FCC, and another definition created by the U.S. Copyright Office. The **FCC** says than whenever you connect **50 or more** residences or living units to a single, common antenna, you have a 'cable television system'. The **Copyright Office** says that anytime you connect **two or more** residences or living units to a single, common antenna, you have a 'cable television system'. We'll leave the legal definations to **CJR**, for now, and concentrate here on how all of this magic works.

MODULATORS And Channels

Remember that if we want to send two or more TV channels down the same piece of cable, we have to start off with the two or more channels operating on descrete, seperate channels of frequencies. More than 40 years ago the FCC established the basis for the present

TV channel system, by assigning certain TV 'channels' to certain, specific, operating frequencies. TV receiver manufacturers, in turn, have designed and sold TV receivers which are also designed to operate on these same frequencies. A table of standard VHF channel frequencies in North America appears here.

A modulator, even the kind built into your KLM or other brand TVRO receiver, operates on a specific frequency. The frequency is determined by either a **'crystal'** which initiates the frequency creation process, or something called a **'free running oscillator'**. A crystal is a small, sealed, electronic device which will create a 'signal' on a specific frequency when the crystal is wired into a special electronic circuit called an oscillator. A crystal virtually guarantees that the frequency of the signal will be very stable, very 'pure', and that the frequency will not 'drift' or change as you use the device. But crystals cost money and the oscillator circuits they plug or wire into are often quite complex. So there is a low-cost approach to the same circuit called a 'free running oscillator'. This is essentially a signal generation circuit minus a crystal. The circuit still produces a signal (known in the trade as a carrier) but the **absolute frequency** of the non-crystal-controlled oscillator **will**

vary; with time and temperature.

Every modulator has an oscillator circuit; without it, it would not be creating a frequency or carrier at all. Most **home** receiver modulators do not use a crystal to create the operating frequency; they depend on a free running oscillator. This is a cost savings to the receiver (modulator) manufacturer. Some modulators sold as 'stand alone' modulator units also do not use a crystal to create the specific operating frequency. They, too, are subject to some variation in operating frequency as thecircuit ages, or alternately gets cold or warm.

A modulator with a crystal 'turns on' very close to the crystal created frequency it is designed for, and it stays on (or very-very close to) that frequency. A free running oscillator 'turns on' on one operating frequency and then as the circuit warms up and the parts heat up, the frequency on the modulator changes. Perhaps not by a great deal, but there is some change nonetheless.

The oscillator creates the frequency for the modulator, but the 'power' of the oscillator is not very great so typically this oscillator signal must be 'amplified' inside of the modulator before the signal is strong enough to be usefull in our applications. The oscillator also is

a 'pure carrier', that is, there is nothing resembling 'intellegence' or information attached to the oscillator's signal. This is what a **modulator** really does; it takes the basic 'pure carrier signal' generated by the oscillator circuit and it 'marries' that pure signal with our video and audio information coming from our TVRO receiver. We'll look, in some detail, how all of this happens in a subsequent portion of this series.

For now, keep in mind that we have the following sub-sections **inside of** the modulator:

1) **An oscillator** that creates the actual signal on a specific frequency;

2) **An amplifier** which boosts the power of the modulator's oscillator to a level or strength that is sufficient to allow us to 'use' that signal, and,

3) **A circuit** (the actual 'modulator circuit') which marries the desired video and audio signal coming out of the TVRO receiver demodulator to the 'pure carrier' created by the oscillator.

NOT ALL Satellite

While it would be expedient to consider an SMATV/Private cable system as an 'all satellite fed' system, using only satellite delivered signals for redistribution via cable to the (subscribing) inter-connected homes, the truth is that such systems are actually designed to funtion with some mixture of satellite fed signals **and** some combination of 'off-air' terrestrial signals. As we shall see, life would be far simpler for the SMATV/Private Cable system installer if only satellite video signals were utilized for cable distribution.

We are forced to 'modulate' satellite signals onto a standard TV channel because of two factors:

1) **The satellite signals** are transmitted to our dish antennas using a type of modulation known as 'FM' or, **frequency modulation**. Our standard TV receivers have been designed to work using a different type of modulation known as 'AM', or amplitude modulation. The two are not compatible and to make it possible for the TV receivers to work with satellite signals, we have to turn the FM signals into AM signals. The TVRO receiver turns the FM signals into 'pure' video and 'pure' audio. Once we have video and

audio available to us, we can then send the video and audio into a new 'modulator' which works as an **'AM'** modulator, and that is compatible with our 'AM' standards television receivers.

2) **The satellite signals** are transmitted in a frequency range which standard TV sets will not tune-in, directly. The TVRO receiver 'down converts' the microwave signals from their special frequencies to a much lower frequency; and then the receiver demodulates these FM signals into basic video and audio for us.

Terrestrial television signals, coming from a VHF or UHF transmitter, are already 'AM' modulated and they are also already operating on a frequency which corresponds to the channels found in the TV set's tuner. When we wish to 'mix' some terrestrial TV signals with some satellite delivered channels, we have to make sure that as we do this we are not allowing either one to interfere with the other on our cable system. If all of the channels we might carry on our cable system were coming to us through the air from VHF or UHF transmitters, we could pretty much depend upon those channel 'frequencies' being stable and in the right 'frequency spot'. That, after

all, is part of the job of a broadcaster operating the station. However, when we depend upon on our own system installed modulators to create some of the channels we will carry on our cable system, now we have to be concerned that our own modulators (oscillators) are operating on the correct frequency to insure that they do not interfere with terrestrial stations to be carried on our cable.

Correct operating frequency is but one of the parameters of concern with an SMATV system modulator. Since most SMATV systems do employ crystal controlled modulators, with high frequency stability, a 'wandering' modulator-oscillator is not a big concern. There are other operating parameters which we will touch on here, just for identification, this month and then look at in greater detail subsequently in this series.

1) **Modulation index.** The process of 'adding' the intellegence (video and audio) to the oscillator 'carrier' involves modifying the original 'pure' carrier. The modifying agent is the video and audio signals. There is a relationship between the **amount** of video signal **and** the **amount** of oscillator carrier. Both units are measured in terms of power levels

each seperately and then the pair as combined. Most commercial quality modulators have a **video modulation control**. This is a system to fix the proper 'ratio' between the raw video signal and the oscillator's pure carrier so that when the two are added together, we end up with a high quality picture on a TV channel frequency. The visual quality of the picture depends almost entirely upon the relationship between the carrier 'power' and the modulation 'power'. Being able to control this relationship and measure or moniter its performance is important.

2) **Oscillator harmonics**. When you create a pure carrier on channel 2 (operating frequency of 55.25 MHz), and then connect the output of that oscillator to a cable system, you must be concerned that 'multiples' of the operating frequency do not also come out of the oscillator (modulator). For example, 2 times 55.25 is 110-.50 MHz. Three times 55.25 is 165.75 MHz. And four times 55.25 is 221.00 MHz. Any oscillator will create its own designed-for frequency, **and** it will also have 'harmonic signals' at 2, 3, 4, 5, and so on times **that** frequency. The main power will be on the

designed-for frequency. But some amount of power will also appear at the output of the modulator at harmonic frequencies (110.50, etc). If **harmonics** of the oscillator-modulator happen to 'fall' inside **another** TV channel in the system, these harmonic signals will cause interference to the other channel. An example.

In our first example, 110.50, 165.75 and 221.00 MHz are not inside of any of the **standard** TV channels. Therefore any harmonics from a channel 2 modulator would not cause cable system interference since there are no standard TV channels affected. However, if we were using a modulator on channel 3, the 'third hamronic' of its visual carrier frequency is 201.75 MHz (three times 67.25 MHz) and 201.75 MHz is within the assignment for TV channel 11 (channel 11 is 198 to 204 MHz; see chart). A table of harmonics appears here.

3) **Sidebands.** When you apply video information to an oscillator carrier signal, you modify the original oscillator 'pure' carrier with the intelligence from the video signal (voltage). A pure carrier, modulated in the 'AM' format, then becomes a **trio** of signals; there is still the original carrier,

plus, there is a new signal **above** (higher in frequency) the original carrier which contains the video information, and **another** new signal **below** (lower in frequency) the original carrier and it, also, contains the video information.

The TV receiver only requires the main (original) carrier **and one** of these two new carriers (called 'sidebands') to reproduce the TV picture. Terrestrial television transmitters eliminate the 'unwanted sideband' with a filter; a device called a (lower) vestigal sideband filter. Thus any terrestrial signals you carry on your cable system have the **one original** carrier **plus one** (upper) **sideband** signal. The lower sideband signal has been eliminated at the transmitter.

Many of the modulators on the market do **not** include lower vestigal sideband filters. That means that when you plug such a modulator into a system, you will now be transmittin through the cable a main carrier signal, and, **both** the upper **and** lower sideband signals. Unfortunately, in terms of frequency seperation, the lower sideband signal

occupies

space down in frequency in the next lower, adjacent TV channel. A channel 3 modulator with both sidebands present will send sideband information out on the cable down on channel 2. As you might suspect, this will cause considerable interference on the cable for the channel 2 signal you have placed there.

Thus selection of modulators becomes very important when you are going to operate acable system with 'adjacent channels'. Using channels 2, 3 and 4, for example, is to use 'adjacent' (or immediately consecutive) channels.

One solution to this problem is to only use these (typically) lower priced modulators when you will be able to get by without using immediately-adjacent channels. You could, for example, use channels 2, 4, 6, 7, 9, 11 and 13 for a seven channel cable system and get by using the lower-priced modulators that come to you without a lower vestigal sideband filter. We'll look at that in some detail also.

4) **Audio generation.** We said that the terrestrial TV transmissions, and the companion TV sets, use a modulation format known as 'AM'. That is partially correct. Actually,

the video portion of the signal is 'AM' **but the audio portion is 'FM'.**

The audio carrier is a second, seperate carrier. It has a relationship with the video carrier which must be prcise. We generally talk bout the visual carrier frequency (see table one, here) but pay less attention to the audio carrier's own frequency. **The audio carrier frequency is always 4.5 MHz above the visual carrier frequency.** Thus if the video carrier frequency is 55.250 MHz for channel 2, the audio carrier frequency is 55.250 MHz plus 4,500 MHz or 59.75 MHz.

The TV receiver locks onto the visual carrier frequency using a form of 'AFC' (automatic fequency control) and then it **expects** the audio carrier to be **exactly** 4.500 MHz away. The audio detector circuits in the TV receiver have been designed so that they will recover audio only if the audio carrier falls in the precise, correct 'slot' inside of the receiver. That slot depends ipon the 4.500 MHz relationship to happen.

There is very little tolerancehere, If the audio carrier,

because of mis-adjustment of the modulator, ends up 4.510 MHz away from the video carrier inside of the TV receiver, the audio will buzz, hiss, crackle and generally be distorted. Most commercial grade modulators attempt to maintain the audio carrier 'offset' between 4.499 and 4.501 (with 4.500 being nominal) MHz.

Just as the visual carrier is created or generated with its own oscillator,m so too is the audio carrier generated with its own oscillator. Thus inside of the TV channel modulator have two seperate oscillators functioning: one for thevideoand one for the audio. The video oscillator operates on some frequency that is determined by the tV channel in use; 55.25 MHz, for example, for TV channel 2. The audio carrier is always at 4.500 MHz, **inside of the modulator,** and it is 'added-to' the vidual carrier oscillator inside of the modulator, electronically.

Even in high quality, big-buck TV modulators for cable, where the **video carrier** is created using a crystal oscillatyor circuit, the audio carrier is almost always created using a 'free running' oscillator. There is typically

not much need for a crystal controlled audio carrier oscillator since at 4.500 MHz, the stability of an oscillator is very good. What does happen, however, is that somebody will get inside of the audio oscillator section of a modulator and 'tweek' on it. This changes the 4.500 MHz operating frequency and instantly you have 'garbled' audio as a result. Of course we will look at that as well.

QUICKIE Review

Let's review the basic points again before we move on to the world of wiring up a basic SMATV headend.

1) **TV channels are generated in modulators.** The modulator has two seperate oscillators; one for the video and one for the audio. There is a precise frequency relationship which must be maintained between these two oscillators, or the quality of the audio will suffer (garbled sound).

2) **The amount of video** (and audio) applied to ech of the respective oscillators determines the overal 'quality' of the video (and audio). Controls or adjustments within the

modulator allow the user to adjust the modulator for optimum picture and sound performance.

3) **Any TV channel modulator will have harmonics.** You elimate these harmonics because you do not want them interfering with the quality of service on 'other channels' in the system. If the modulator unit does not have this type of filtering built-in, you add it externally with a device called a 'bandpass filter'.

4) **You may use virtually any working modulator** if you do **not use** immediately adjacent channels on your SMATV system. But if you are going to 'stack' channels one after

the other (2,3,4, etc.) you must use a quality modulator which includes a built-in 'lower vestigal sideband filter'. Failure to do this will disrupt the reception quality on all channels which have an immediate-upper-channel in use.

WHERE Signals Come From

As illustrated here, there are four basic signal sources available to the SMATV system planner. There are off-air **VHF** signals (channels

2-13) which can be placed on the cable on either their original channel, or an alternate channel. There are off-air **UHF** channels which must be frequency converted to VHF (i.e. channel 43 to channel 3) before being placed on the cable.

Both the VHF and UHF 'stations' maintain their own modulation levels, their own frequency stability, their own 4.500 MHz 'offset' for their audio carrier, and, they eliminate their own 'lower sideband' signals. All you have to do is to insure that their 'levels' or strength is proper for your SMATV system.

There are also **video signals** available; from a tape deck if your system will use any taped programming or a local, live camera if your system will have one or more local surveillance cameras as part of the system. And there are the 'distant' satellite delivered, microwave signals which you reduce to video and audio signals before you apply them to your system modulators.

All local video (and companion audio) sources require modulators and depending upon the channel configuration selected, external 'filters' (or having originally selected modulators with built-in filters).

The function of the **'Headend'** is to insure that each of these seperate channels is individually 'treated' with whatever electroni magic as

may be required to make the pictures and sound of high quality to the TV sets plugged into the cable distribution system.

1) **VHF Channels.** If you are able to carry the VHF off-air signals on the original tranmission channels, you can sve some money and long-term headaches. Let's assume you have local television broadcasting on VHF channels 2,4,6,7,10 and 13. Now, what determines whether you can carry these channels 'on-channel' or must shift them to a new channel?

What you are trying to avoid is 'interference' between the signal you deliver to the TV set via your cable system, and, any signal that might float through the air from the TV transmitter itself and wind up inside of the TV set. What happens is this.

When you are close to the TV transmitter(s), there is a large amount of signal present in the air. You will capture some of that signal with your roof top antenna. You will then carry that signal to the headend in a pice of cable and plug it into a single channel VHF processing system. Then you will add that channel to the other channels in the system and carry them all, together in one cable, to the TV receivers served by the system.

Ideally, the only signal the TV sets receive on that channel (call is 2) should come into the TV set from the cable connection you make. However, if the signal level from channel 2 is very high in your area, some signal may leak **directly into the TV set** from the air around the set. When this happens, the TV set gets a double-shot of our channel (2). Some of the signal comes into the set's innards from our cable service; some more comes into the set from the air around the set, working its way into the set's internal wiring. Now the TV receiver has channel 2, **twice.** Only, **one** of the signals takes longer to get to the TV set than the other. The one you pick with an antenna travels through the antenna, through the cable, through the processing equipment and finally to the TV set. The other signal, the one 'in the air' around the set, travels 'directly' to the TV receiver. Both signals are displayed on the TV screen. But they are not in 'sync' since the one coming through the cable has travelled further, and slower, than the one through the air. The result is a smeared picture, called 'ghosting'. You see the main picture on the screen, and then to the right (or perhaps to the left) you see a 'ghost image' or secondary picture. Viewers will not tolerate this and you have a problem.

The usual 100% solution to this problem is to take your strong local

channel off of the original channel and placeit on another channel. Let's say we have so much 'direct pick-up' of the local, strong channel 2 signal that we must convert the channel to channel 8. What type of decision is this?

1) If we cannot use channel 2 with channel 2, 'on channel', the chances are quite good that we cannot use it for anything else either. Yes, there are techniques for 'saving' a situation like this, called 'phase locking' the local channel 2 signal to another substitute channel of service, but the costs for an SMATV system are prohibitive. So for most SMATV systems, having to move a local channel off to another channel is the same things as losing use of that channel at all. What was a 12 channel dial just became an 11 channel dial. Or worse if you have several strong local signals.

2) If we can 'process' the off-air signals **on-channel**, we can use relatively inexpensive 'strip amplifiers'. This works out to between $250 and $450 per channel using high wuality units. If we are forced to move channel 2 to anotehr channel, we have two options. First, we could employ a

crystal controlled channel converter to move channel 2 to 8 (for example). Then once on channel 8, we would need to further process the new channel with its own 'strip amplifier' (operating on channel 8) to establish the signal 'level' we will need for the SMATV system. This is a package of equipment costing upwards of $700 if done with professional equipment. Or, we could use a device known as a heterodyne processor. This is a sophisticated package that has one channel as the input (channel 2) and another as the output (channel 8) and in between the two there is a considerable signal filtering, automatic gain control circuits and so on. This is tyupically a single-packed-rack mounting unit; price in the $1200 region.

Staying 'on-channel' is obviously the most cost effective way to go. **There is a test you can perform** to see, in advance, whether you can get away with this in your installation. Inspect several of the residential units which your SMATV system will serve. Go in and **disconnect** either **built-in** (rabbit ear **antenna**(s), or any external antenna from the customer's TV receiver. Now tune through the dial. With no antenna conencted to the TV receiver, **can you still see** a

picture and hear sound on any channels? **Yes?** That means you **do have** sufficient 'direct pick-up' to cause you problems. If the picture is so weak as to not lock 'in sync' and the sound is garbled and noisy (or, gone altogether), you are home free. Your cable delivered signal will be strong enough to override that little bit of signal being picked up directly by the TV set's innards. You need todo this at several locations, on all floors of any multiple story buildings, since VHF signals tend to be spotty even in close-in to the transmitters.

UHF Channels. All ultra high frequency channels must be 'down converted' to a **VHF** channel. How come? Well, most of the commonly available cable distribution equipment is designed for the VHF range only. True, there are MATV systems around that distribute UHF channels directly on UHF ('on channel') but they are typically more troublesome to maintain and perhaps not as satisfactory as moving the UHF channels to a 'spare' VHF channel.

The most common, cost-effective way to do this is to install a single channel UHF to VHF crystal controlled converter between the UHF off-air antenna and the VHF single channel strip amplifier. This would convert say channel 43 to channel 6. The output of the crystal controlled channel converter then plugs into a channel 6 'strip

amplifier' and from that point onward you treat the UHF channel jsut as if it was originally a VHF channel 6 channel.

At this point it would be good to remind you that if you moved any VHF channel off of its original channel to a new VHF channel, or if you have any UHF channels in your system, that the 'frequency integrity' of the channel conversion equipment is of some concern. It is possible to acquire non-crystal-controlled converters to move channel around. They work, but they may not have the fequency stability to insure that you channel 2 signal stays squarely on the 'assigned' channel 6 spot. If the oscillators 'wander' around, you could have 2 half way into 7 or 9, or 43 halfway into 5 and in the process screw up reception on those adjacent channels. You avoid all of this by sticking to crystal controlled converters (or heterodyne processors which are also, by design, crystal controlled).

3) **Local Video.** A video signal from a surveillance camera, or a video and audio pair of signals from a TVRO receiver, are fed to appropiate modulators to get into the system. Sufficient discussion of the modulator parameters has already taken place for now and you are already aware of what to watch out for when selecting modulator

equipment for an SMATV job. Let's look now at how we beging to 'mix' these channels together.

BASIC SMATV Sysem

Let's assume for discussion that our SMATV system is but four channels, allk four of which come from satellite. **This system here, on page XX.**

We have selected WGN, ESPN, MTV and CNN2 for our service channels. They all fall on a single polarization (vertical) from a single bird (F3R). Thus with one dish, one single pole feed and one LNA, we have the four signals desired.

There are there seperate ways to do this; only one is **shown** here. In the system shown, we have four seperate down converters, each of which corresponds to a single transponder. We drive those four down converters with a microwave four-way signal splitter to provide seperate outputs to each of the down converter inputs.

The equipment will typically be installed indoors. Therefore in this example we run a length of 1/2" or other suitable hardline from the LNA output to the input of the four-way micrwave signal splitter. We will be in type 'N' fittings all of thw ay, so far. The four-way splitter

divides the available satellite microwave signal power into four equal parts. Each of these "1/4th level" signal voltages will then appear at the input to the down converters. The down converters will frequency-shift the microwave satellite signals to the 'IF' range of the companion demodulator/receiver units. By dialing up or selecting the appropiate down converter frequencies, we convert inside of each down converter/receiver package the incoming selected satellite microwave signals to baseband video and audio. This is the 'traditional' approach to such a system, but by no means the only approach.

Another popular approach is to employ a single down converter unit which takes the full 3.7/4.2 GHz microwave satellite 'band' and coonverts it to a lower 'block' of frquencies; such as .95/1.45 GHz (DX) or .25/.75 (AVCOM, S-A etc.). In this case the single 'block' down converter typically mounts at the antenna in a weather tight housing and low cost RG-59/U, RG-6/U or RG-11/U cable is run from the output of the block down converter to the indoor equipment. Once inside, a UHF region signal splitter is employed to divide the available signal voltages into (in this example) four parts; 1/4th of the origninal total going to each of the seperate, single channel,

demodulators.

A third approach, used extensively several years ago but less ofte now, is to use single convertion receivers and signal isolators. IOn this case a microwave region four way splitter would be installed after the LNA and the four-way-split microwave signals would be fed into four seperate single-conversion down converters. Between the splitter output and the input to the down converter would be a microwave 'isolator'. This is required because single conversion receivers feed 'back' their own local oscillator signal(s) through their inputs to any equipment attached to the same antenna. In our example, a receiver tuned to ESPN could, for example, cause reception interference to the receiver(s) tuned to WGN and/or MTV. The isolator should cure that problem. Then the demopdulator untis provide video and audio baseband signals to the modulators.

The output of the demodulators will be video and audio; the so-called **baseband** signals. The video output connects to the video input on the modulator; the audio output connects to the audio input on the modulator.

There are some potential compatability problems here.

Most of the demodulators in use dor semi-commercial and commercial

applications provide a one volt peak to peak video signal. Most of the modulators available happen to want to see one volt peak to peak video, for 85% modulation of the video carrier. Most modulators provide a modualtion control to set the modulation 'percentage', and many receivers provide a handy 'video level control' to raise or lower the actual video signal level coming out of the TVRO demodulator.

A few of the modulators available (Blonder Tongue's ESM and TVM series, for example) provide a meter or LED indicator to tell you when you have reached the proper modulation control level setting with either the modulator's video gain control, or the receiver mounted video output level control.

The 'depth' of the video modulation is an important parameter for high wuality pictures. A real perfectionist would hook up an oscilliscope and measure the modulation. That is not entirely necessary; a reasonably good quality television, hooked to the modulator directly, can do the same thing. We'll see how, later in this series.

Most of the **modualtors** used for semi-commercial and commercial applications has a 600 ohm **un**balanced audio input connection. Most of the **de**modulators have a 600 ohm audio **un**balanced output connection. Seemingly, it would be a matter of connecting one to the

other. There are a few curves in there however.

Balanced versus unbalanced audio. In a balanced audio system, both sides of the audio line 'float above ground'. That means that neither of the audio connections coming out of the receiver are at chassis ground. An RCA fitting, with a tip that inserts into a jack and a 'ring' that slides over the chassis mounted fitting/connector is not a 'balanced connector'. Because one side of the line goes to chassis ground, it is always unbalanced. The output fitting on the DX series receivers, for audio, is an RCA jack. The output fitting on an AVCOM 66T series receiver is either an RCA jack (unbalanced) or a four screw terminal strip. One might **suspect** that the four terminal-strip is some type of balanced **or** unbalanced audio **selection**. Not so. Internally, the four terminal screws are connectedd in an unbalanced-only configuration with the furthest right screw being the hot or center connection for audio and the nect two to the left being simply chassis ground. Thefurthest left terminal screw is not connected up.

Some modulators (Blonder Tongue TVM series as an example) give you an optional approach to connecting up the audio. On the TVM, you have a pair of red colored terminals on the rear panel, adjacent to a

'grounding terminal lug'. If you had a 600 ohm balanced audio source available, such as you find in Microdyne receivers for example, you would do best to connect the 600 ohm balanced audio to the two red terminal screws of the TVM modulator. Now you would have balanced audio connecting to balanced audio. On the other hand, if your receiver had unbalanced audio, you would connect the hot lead of the audio (the center pin on the RCA jacked-end) to one of the red terminal screws of the TVM (either of the two) and you would connect the interconnecting cable shield (ground wire) to the chassis 'grounding terminal lug' on the TVM; unbalanced audio to unbalanced audio.

Given a free engineering choice, there are some advantages to having balanced audio in the system. By keeping both sides of the audio line 'above' or away from the chassis ground, you reduce or eliminate the possibility that 'ground loops' will appear in the audio circuit. You know when you have a ground loop; the audio 'hummmms' on you. When you elect to use one side of the audio line as the chassis ground, you introduce the possibility that any extraneous 'AC' (60 cycle stuff) in or around the chassis will find its way into the audio line. However, as noted, very few of the TVRO receivers fo offer true unbalanced

audio, and even fewer of the modulators around accept unbalanced audio.

Some TVRO receivers offer an audio output level control (DX DSA 643) while others do not. Most if indeed not all of the semi-commercial and commercial grade modulators offer at least and audio modulation control. So like the video controls 'at both ends', it would appear that you have more than ample opportunity to 'set' the audio modulation amount to a pleasing level.

There are at least two audio adjustments which seem to have the same effect on the audio you are listening to or measuring. One is the true modulation control. Since this is an FM (frequency modulation) system, there is another control which may seem like it does the same thing. This is the deviation control; it sets how 'wide' or 'narrow' the frequency 'modulates'. Thedeviation control is not readily accessible on most modulator units; it is possible to find on the Transifier (Pico Satellite) AVM100X series, for example. The rule here is that you carefully read the instructions with any modulator, and if you are tempted to start tweeking on 'unmarked' adjustments, don't.

There is one more control which also has the effect of adjusting audio

'level' in the receiver, although when you mess with it you are really living dangerously unless you have the proper test equipment. This is the **audio carrier level** control.

The audio carrier requires far less 'power' to the TV receiver than the video carrier. Standard off-air TV transmitters operate so that the audio carrier is at least 10 dB weaker than the visual carrier level. That means that if they are transmitting 100,000 watts of 'power', the vidual carrier is 100,000 watts (100 kW) but the audio carrier is 10 dB weaker that this; or, 10,000 watts (10 kW). Cable system operators learned many years ago that when you 'stack' immediately adjacent channels (such as 7,8,9, etc.) you cannot operate your audio carrier levels as strongly as they do 'off the air'. **For this reason you need to be able to adjust your audio carrier level to a lower level.** This reuires some form of signal strength or field strength meter. We'll look at meters as a measurement tool subsequently in this series. For now, know that the **most desirable** audio carrier level is **15 dB below** the visual carrier level. That means that you measure the visual carrier level with a field strength meter (FSM), and then measure your audio carrier level; tweeking on the audio carrier level control, set it so that it is 15 dB weaker (or

-15 dB) than the visual carrier.

And if you don't?

When channels are stacked one after the other on the dial, the TV set in the home is asked to seperate those closely spaced channels. The average TV set can do this provided there is a close 'balance' between signal levels on adjacent channels. However, if the signal level on channel 3 is considerably stronger/hotter than the signal level on channels 2 and 4, on thecable system, the TV set will find it difficult (or impossible) to produce a clean channel 2 or a clean channel 4; there will always be some 'channel 3 interference' in the picture (channel 4) or sound (channel 2). By reducing the audio carrier level on each channel to a point that is 15 dB weaker than the adjacent video carrier, and, 15 dB weaker than its own video carrier, we give the TV set a little extra 'edge' in making clean pictures (and sound) on the adjacent channels. We'll take a long look at channel 'levels' in this series as well.

COMBINING The Channels

Up to this point we have each channel being created indivisually, in

the headend, with its own signal processing equipment. Now, how do we get them all together into a single cable?

There are three techniques for doing this; all pretty much follow the same approach, but the hardware differs.

1) You never directly 'combine' adjacent channels together in the same 'string', and

2) You always combine channels by low and high band grouping.

Now, what does tht mean?

Most of the modern semi-commercial and ommercial modulators have a **pair** of output terminals on the back plate or cover. They call these 'looping outputs'. Logic tells you that you only need one of these two outputs to connect that channel to some master connection where all are combined together.

What you do is stack the modulators or signal processor equipment in the rack in the sequence that you will 'combine' the channels. Here are the typical combining sequences for a 12 channel system:

1) String One : Channels 2,4,6.

2) String Two ; Channels 3,5.

3) String Three : Channels 7,9,11,13.

4) String Four : Channels 8,10,12.

Any lesser combination than 12 channels would merely eliminate the 'string' or the channels not in use.

If the modulator has a built-in 'looping output connector series' (i.e. two output connecters per modulator/processor unit), you start off by taking the **first channel in the string** (2,3,7 or 8) and insert a 75 ohm terminatyor in **one** of the two looping output connectors. 75 ohm terminators are simply 'F' fittings with a tiny 75 ohm resistor soldered into the fitting. That leaves you with one unused output F fitting on those (four) channels. Now make up a short patch cord with an F fitting on both ends. Connect it from the unused output connector on channel 2 to **either of** the two output connectors on the channel 4 unit. Next make up another short patch cosrd of RG-59/U and repeat the process connecting from the unused channel 4 connection to one of the two connections on channel 6. Now move to the next string, starting with the terminator, and ending with the last modulator or processor in the string.

When you are all done, you will have four strings wired up, with one empty chassis mounted F fitting on channels 6,5, 13 and 12. Now take a two-way hybrid signal splitter (**hybrid** is important!) and mount it so that you can run a patch cord from the unused fitting on channel 6

and the unused fitting on channel 5 to the two **output** fittings on the hybrid splitter. Do the same thing with the channel 12 and 13 unused fittings, connecting them to the **output** side of the **second hybrid** splitter. Now we have two fittings left unconnected; the 'input' side of the two hybrid (two-way) splitters. Find either one more hybrid splitter or find a 'Low Band/HMigh Band' splitter and hook it up in the same manner; the unused input side of the **low band** (channels 2-6) double string to either side of the third hybrid, or the **low band side** of the Low/High splitter; the unused input side of the **high band** (channels 7-13) double string to either side of the third hybrid or the **high band** side of the Low/High splitter. **Now you have** one **unused fitting**; the input side of the last (third) hybrid, or the input side of the High/Low splitter. This is your combined output for all 12 of your channels (or whatever number you have). Into this port you will connect your cable 'trunk line' to feed 12 channel service to the homes you are connecting up.

This technique makes use of the internal 'combining networks' found in the modulators or processors. Not every modulator ever built has such an internal combining network. And, as we shall see, there are special circumstances where using the internal combining networks

is not the best approach. So what **other techniques** are available?

All Hybrid splitters. If you wish, you can 'turn around' two and three and four way hybrid splitters and use them as 'external' (to the modulators/procesors) combining networks. A pair of **three-way** hybrids, using the output sides as inputs, would combine channels 2,4,6, and, channels 8,10, and 12. A two-way would combine channels 3 and 5. A four-way would combine channels 7,9,11, and 13. Then you would use more two-way units to combine those 'strings' as we did in the preceding example.

Combining network. In the CATV world, it is possible to purchase a neat appearing rack mounting 'external combiner' that builds all of the seperate hybrid networks into a single package. You have 12 (marked) input channels and one (marked) combined output. It will cost you about twice as much as using seperate hybrid combiners but it sure cleans up a wiring "rat's nest" in the process.

LEVELS To Set

One of the basic premises of cable systems is that all cable has 'loss'. You are familiar with this since you know that you can use only a certain amount of cable between your home installation down

converter and your indoor demodulator.

There are two rules of thumb concerning cable 'loss'.

1) **The smaller** the physical size of the cable, the more apt it is to have 'high' losses.

2) **The higher** the frequency of the signal being carried by the cable, the greater the loss of power for the signal.

Any cable you buy has a known loss factor. You can check the specifications of the manufacturer to determine what the loss will be, at different frequencies, per foot or per hundreed feet of cable. **These are very important numbers.**

Let's make some statements and then plug some numbers in.

There is a desirable 'signal level' to be delivered to the TV set antenna terminals by the cable system 'drop' (the final connection to the TV set is called a 'drop'). **That number in cable jargon is 0 dBmV.** In TV installation terrms, 0 dBmV is not zero signal; it corresponds to 1,000 microvolts where one microvolt isd one-millionth of a volt. We determine how many microvolts or how many dBs of signal we have at any point in the system (including the output of the headend modulator/processor units) with a field strength meter (FSM).

Now the numbers.

Cable TV planners like to use the dB measurement system rather than the older microvolt system because you can directly add and subtract dBs whereas microvolts have many more numbers to handle to each computation.

1) If the TV set should have 0 dBmV minimum signal to produce a clean, clear picture, and we have +42 dBmV signal coming from our modulator at the headend, how much cable can we lay between the modulator's +42 dBmV output anfd the TV set 'drop' and still have 0 dBmV remaining?

The answer is obvious. We can have **42 dB of cable loss** between the two points and still reach the TV set with an adequatee picture. Now, how much cable is 42 dB of cable? The answer depends totally on what type of cable we are using. And, it also depends upon the frequency of our signal. Remember, cable loss is a function of cable length AND the operating frequency of the signal.

Smaller cable has more loss than bigger cable; higher channels (frequencies) have more loss than lower channels (frequencies).

Some example numbers.

1) Our cable has 3 dB loss per 100 feet at channel 2, and,

2) 6 dB of loss per 100 feet at channel 13.

That means we could transport the +42 dBmV signal through 1,400 feet at channel 2 (42 dB divided by 3 dB loss per 100 feet) or through 700 feet of the same cable at channel 13. And still have 0 dBmV signal left for the TV receiver. Those numbers, 6 dB loss at channel 13 and 3 dB loss at channel 2, are 'ballpark' numbers for **some** of the RG-59/U cable now on the market.

Another set of example numbers.

3) Our cable has 1 dB loss per 100 feet at channel 2, and,

4) 2.5 dB loss per 100 feet at channel 13.

Now we could transport the channel 2 signal through 4,200 feet of this cable or our cvhannel 13 signal through 1,680 feet of the same cable. And still have 0 dBmV signal left at the end. These numbers (1 dB at channel 2, 2.5 dB at channel 13) are 'ballpark' numbers for **some** of the size .412 aluminum jacketed cable commonly used in cable systems.

There is an obvious design problem here; we copuld travel through more than 3/4ths of a mile of cable at channel 2 but less than a third of a mile of cable at channel 13. We probably want to travel through the same elngth of cale with all 12channels (or channels 2 and 13 in

our example) so how do we 'compensate' for this considerable difference in cable loss?

The most obvious answer is that we accept the channel 13 number (1,680 feet in .412 type cable; **always** check the manufacturer's **exact** specifications **before** planning ANY system) and design our system around that shorter num,ber. If, it turns out, we can reach our intended end-of-cable destination before we run out of signal, **at channel 13**, out problems are simplified. But suppose we must go say 2,300 feet to reach our last home location; what then? The answer is that we must place an amplifier in the cable line to re-amplify the signal. We'll return to amplifiers seperately.

Most cable systems do not start at the headend, run through a **single** piece of cable, and end up at a **single** TV sdet. Most cable systems serve dozens of hundreds of TV sets along the way. So how do we get the signal to these additional sets that are not located at the end of the signal line?

First of all, we take a close look at the area to be served. Suppose it is a two story building with some number of outlets on each floor. We know where it will all begin; where all 12 channels are combined into a single outlet. If the distance from the headend equipment to the

two floor levels is more than 25 feet or so, we can install a length of cable from that **single** combined headend output to a convenient location where we will isntall a two-way (hubrid) splitter. The cable from the headend to the first cable-line splitter can be called a **'trunk'** since this is our 'main' signal line. Then from the (hybrid) splitter we have two lines outputting; **one to each** of the two floors in the building. We will call this new cable, leaving the splitter, **'feeder cable'**. We hang this name on it because it will directly connect to TV outlets on each floor, feeding signal to each.

The splitter has loss. All signal splitters 'lose' signal simply because they take whatever signal is fed into their input and they divide that total available signal into two, three, four, six or eight more or less equal parts. So they don;t actually lose (very much) signal; they simply divide it into parts. That 'loss' however is improtant to us because then the signal is split into two parts, we now have only half as much available to us for subsequent cable runs on **either of** our two 'feeder lines'.

Here is an important number to remember. An ideal signal splitter will 'lose' 3 dB of signal in a two-way split. There is no such thing as an ideal signal splitter so it is safe to asszume the signal 'loss'

through the two-way splitter is 4 dB (a threee-way splitter typically will 'lose' around 5.5 dB per split leg while a four-way splitter will typically lose 7 dB per output leg). When we resume our calculations of signal 'loss' or degradation between the neadend and the end of the line(s), we must now add 4 dB of loss into our calculations to account for the splitter. That is the equivalent of shortening up the maximum cable length (remember, it was 1,680 feet for type .412 cable) by 4 dB of cable; or 160 feet of cable.

Now we have two seperate feeder line, **one for each floor**. And off they go to provide multiple channel TV service to the TV sets located there. We get TV signal **out of the feeder** by 'tapping into' the feeder. The device that does this is called a 'signal tap', or to cite a specific type of signal tap, a 'directional tap' (also known as a directional coupler). This is a passive device (it uses no electricity to operate) which has an input and an output connector, and one, two, three, four and more 'tap connectors'.

Directional taps (DT's) are available in various 'values'. Here is what they do and they they have numerical values.

1) You will install a directional tap in the feeder line at a location which allows you to serve one or more TV outlets. You will

select the DT based upon two parameters. One of these is the number of TV sets you wish to serve at that location. Let's assume you have two TV sets to serve at out first location, either in the same residencee or because you were careful or lucky, you can locate a DT where you can reach two seperate residences from the same DT location. So our first DT will have 'two tap connections' or outlets.

2) At each location where a DT will go in line, you have some known amount of signal strength. You can (and in fact you MUST) calculate how much signal will be present **on the feeder line** at that tap's location. You calculate this by starting off with the total amount of signal available to you on the highest frequency channel (+42 dBmV) and then subtracting all of the losses up to that point.

A) Assume we have 25 feet of .412 trunk and 100 feet of .412 feeder. That is 125 feet of .412 cable which we shall say has 2.5 dB loss per 100 feet. That works out to 1.25 times or 2.5 or 3.1 dB of cable loss.

B) We also have that trunk splitter that creates our two feeder lines, and we knowit has 4 dB of loss.

The total loss, between the headend and the first DT location is 3.1 plus 4 or 7 dB. If we started out with +42 dBmV of signla, and we

have lost 7.1 dB of signal getting to the first DT location, we now have 42-7.1 or (+) 34.9 dBmV of signal **in the cable** where the DT will install.

Now, to get from the DT's actual location to the furthest TV set outlet inside the residence, we have 100 feet of RG-59/U cable. That cable will have 6 dB of loss, in our example, at channel 13. So now we have an additional 6 dB of loss, before we reach the TV set, so our (+) 34.9 dBmV signal has now become 34.9-6 or 28.9 dBmV.

That is an important number since directional taps have something known as an **isolation** value. So what's next?

Just as there is an optimum signal level for a TV set (0 dBmV) so too is there a 'maximum' signal level if we want to avoid 'overloading' the TV set with too much signal. Generally, that level would be around +10 dBmV. If we considered the directional tap to be a loss-less device, one that just pumped all of the signal available at that point straight to the TV set, we would have +28.9 dBmV of signal going to the TV set. If +10 dBmV is a safe 'upper limit' for too much signal, that tells us that somehow we have to reduce the signal actually going through the tap by some considerable amount.

Isolation does this. Built into the DT is a circuit that be design

reduces the amount of signal that tap allows to flow from the feederleine through the 'tap connector' to the RG-59/U line that goes to the TV set. This circuit is knows as an isolator and it simply controls how much signal is available from the line to the TV set.

Taps are available in various 'dB isolation values'; 32,29,26,24,22,18,15,12 and 10 are fairly common values. What you have to do is to select the proper DT, having both the appropiate number of 'tap connections' **and** the proper amount of isolation for **each tap location.** In our example, we would select a tap with 29 dB of isolation because we found out that we had +28.9 dBmV of signal left when we calculated how much signal we needed to reach the example outlet with 0 dBmV after 100 feet of final-leg RG-59/U cable.

You repeat this calculation process for each tap location, starting off with the amount of signal you have at the headend and then summing all of the loss factors (cable and splitters) along the way. There is one more loss factor to consider. The DT itself.

While the DT is 'passive' and it uses no operating power, **it does remove some of the signal in the feeder line** to go the the TV outlet(s) connected to that tap. So as we move 'down the line' from

the headend to the end of the cable run, we have to keep adding additional losses as we go:

1) Cable loss in trunk

2) Cable loss in feeder

3) Loss in splitter(s)

4) 'Through' loss in each DT (loss between the feeder line input and the feeder line output)

These losses will be cumulative as you go further and further from the headend. Then for each drop along the way, you must add in the loss of the RG-59/U (or other type) of drop cable connecting the individual sets to the feeder line proper.

DT losses vary as a function of isolation value. The **greater the isolation** (29, for example) the **lower the DT 'through loss'** added to the feedline level. The lower the isolation (10 dB for example) the greater the DTs loss contribution to the feeder line. Loss values such as .3 dB are common for high isolation DTs while losses such as 1.5 dB are common for DTs with low isolation values. Each DT manufacturer will tell you what 'feeder line' losses to add to your calculations for each value of DT.

FLAT vs Tilt Loss

We noted earlier that cable has more loss as the frequency of the signal increases. Channel 13 has more loss than channel 2, for example, in all cable.

Not everything the signals travel through has this type of loss. Signal splitters and DTs, for example, have **'flat loss'**. That is, their loss is the same at channel 2 **and** 13. A splitter with 4 dB of loss at channel 2 will have 4 dB loss at channel 13.

Therefore your system calculations have to be twin calculations. In one column you are calculating the total system loss at the lowest channel (2) and in another parallel column you are calculating the loss at channel 13. But there is a problem coming, as you might suspect.

If we have designed the system for maximum loss factor at the highest channel (13), what is happening to the lowest channel(s) through all of this? Remember that there is a **maximum level to the TV sets** as well and as we approach the end of the feeder line where we are nearing the point of no return at channel 13 (0 dBmV delivered to the last set through the last DT) where do you suppose the channel 2 signal level is at this point? The answer is that it will be much-much higher, since it has not suffered as much 'cable loss' as

has channel 13.

You can pre-calculate this difference, and in fact you will have to in laying out the system. Then before you turn the system on, you will have to '**compensate**' for this extra signal on the lower channels.

Let's assume you determine that at the end of the line, last tap out of the last DT, you will just have 0 dBmV at the end of the frop line to the TV set; on Channel 13. Now let's assume you calculate that your channel 2 level will be 15 dB stronger that this (the equivalent of 1,000 feet of cable loss). Ideally, wewould have channel 2 at 0 dBmV **and** channel 13 at 0 dBmV at the **same** point. The easiest, safe, way to do this?

Tilt the signal levels at the headend.

Tilt means that there is an on-purpose difference between the lowest and highest channels, as they go through the cable system., Let's concentrate only on that end-of-feeder line tap outlet for a minute. Our calculations tell us that there will be 15 dB more signal on channel 2 than on channel 13 at that location. **One solution** would be to **turn down channel 2 at the headend by 15 dB**; rather than operating at an output level of +42 dBmV as we started off with intially (for channel 13), we will lower it 42 - 15 or to +27 dBmV.

Now they will both come out **even at the end.** But what about closer to the beginning, say the first drop?

Remember that we had 3.1 dB of cable loss plus 4 dB of splitter loss as we entered the first DT. If we whacked off 15 dB of channel 2 signal at the headend, we would be around 13 dB weaker on channel 2 than on channel 13 at THAT tap location. Hummm.

That shows us that while we must consider the signal ranges at the last tap in the line (the one MOST affected by cable tilt differences) we must **also consider** the reverse effects of tilting the headend output levels at the imtermediate taps as well.

There are two solutions to this one.

1) Install into the various tap lines some passive 'tilt equalizer'; devices which allow you to articially reduce the low band signals while passing the high channel levels with no attenuation. This is a pure way to do it, but it raises the cost of those drops by around $6 each for the passive 'tilt equalizer'. There is another solution.

2) Remeber that while 0 dBmV is the minimum and also the recommended signal level to reach the TV receiver antenna terminals, that +10 dBmV is the maximum. **And anything in between these**

two numbers is very acceptable.

If we would be 13 dB too low on channel 2 at the first tap, or 15 dB too high on channel 2 at the last tap (when we operate the headend on channel 2 reduced 15 dB in the first instance, or level with channel 13 in the last instance), why not 'split' the difference; that is, operate channel 2 so that it is 8 dB lower than channel 13 at the headend? Now we would be 0 dBmV on channel 13 and +5 dBmV on channel 2 **at the first tap** outlet, and 0 dBmV on channel 13 and +7 dBmV on channel 2 **at the last drop**. Everyone is more or less happy, and the system operates within the proper **window** without any add-on-cost passive tilt equalizers.

As you may suspect by now, we are not simply dealing with channels 2 **and** 13; if we have a 'fully loaded' system of 12 channels, we have 12 channels to adjust andbalance. A typical headend output level chart, for our example system, might look like the following :

CHANNEL	OUTPUT LEVEL
2	+34 dBmV
3	+34 dBmV
4	+35 dBmV
5	+35 dBmV
6	+35.5 dBmV

7	+40 dBmV
8	+40 dBmV
9	+41 dBmV
10	+41 dBmV
11	+41 dBmV
12	+42 dBmV
13	+42 dBmV

As the table suggests, we are going up in frequency (and channel number) as well as output signal levels for the channels. Channels 2-6 are called 'lowband' and they operate between 54 and 88 MHz. Channels 7-13 are called high band and they operate between 174 and 216 MHz. There is a considerable 'spectrum space' between low and high band, and thus there is a considerable 'jimp' in headend output power as we jump from 6to 7.

THE TV Set As A Test Instrument

With considerable experience and a sixth sense for what is wrong and right, it **is** possible to use a television set as a test instrument. However, this caveat; **there is no substitute** for a field strength meter (FSM) to properly set up an SMATV system.

At the headend. The first place you need to 'test' the signals is at

the headend. Any modulator channels require adjustment of the video modulation, the audio modulation (level) and perhaps the ratio between the visual and aural carriers. You can use the TV set with modest precision to adjust the video and audio modulation levels. The ratio between the visual carrier and the audio arrier (remember, the audio carrier should be 15 dB weaker than the video carrier) is another matter.

Recall that a TV set has optimum input level parameters. On the cable system itself, we are spending considerable time (and money) to insure that **each channel** is arriving at the customer receivers at about the same signal level, and within a 'window' of 0 dBmV to +10 dBmV. You can**not** run a cable from the output of the modulator directly to a TV set and expect to analyze the quality of either the video or the audio.

A typical SMATV type modulator has an output level of between +40 and 60 dBmV. That is several tens of thousands times as much signal as the TV set is designed to handle properly. There is no danger of blowing anything up; it is simply that when you put too much signal into a TV receiver, the TV set no longer does its job properly and what you see on the screen or hear in the speaker is no longer a proper

representation of what a subscriber will see.

Most SMATV type modulators have an output 'test port' or tap. This is usually marked "-30 db" or "TEST". An output test port that is marked "-30 dB" means that whatever output level you have available at the real output connector will be 30 dB 'weaker' at the test point/port. A modulator that is capable of putting out +60 dBmV will still jave a +30 dBmV (60-30) at the outputTEST port. That is too much signal for a typical TV set to handle gracefully. If the modulator has a master 'ouput level control', you can reduce the output level with that control and simultaneously reduce the output level at the test port. Most such controls cover a 20 dB range which means that you could lower the level at both the regular and the test port by 20 dB; to +10 dBmV in our example. You should do this **before** making any serious critiques of the video and audio.

The video modulation control establishes the percentage of modulation; the ratio between the carrier level and the video signal thatis used to add 'intellegence' to the carrier. A properly modulated carrier will have 87.5% modulation. That is a difficult level to **maintain,** however, sincee the amount of modulation changes constantly as the video scene itself changes. With a TV set as your

own test tool, anyplace **below 85%** and **above 55%** probably a reasonable goal to shoot for.

Too much video modulation. The picture has a bleached-out white look; white objects appear super-white, all detail is lost in them. Black objects 'smudge' and if the video modulation is close to 100% or beyond, the TV set may 'buzz' when there is an excessive amount of white or light colors on the screen. Turn it down.

Too little video modulation. The picture looks washed out, the yellow and blue and white colors seem to be behind a filter and there is no 'snap' to the video. Contrast levels are low. Turn the video up.

If the modulation is being adjusted, in this manner, during regular programming, stick with it a few minutes to insure that when there are many bright colors the picture does not **over**modulate and bleach out (or buzz). Most people tend to set the video modulation 'too high' rather than too low, initially.

This would be a good point to suggest that the color level, the brightness, and the contrast on the test receiver should be properly adjusted **before** you do much else. There are two ways to do this, in the field.

1) Tune in a regular terrestrial station and make sure the picture looks like a quality picture should look. Then without touching any of the three above mentioned controls, check out the modulator channel.

2) Switch the satellite receiver to a channel with color bars up (TR 22, for example, on F3R). Adjust the TV set for proper color bar display. Then leave the TV set controls alone and proceed to the modulator channel.

The audio level controls are very difficult to set properly on the modulator unless you have a reference to go by. The **best reference** is a local, terrestrial TV station signal. Adjust the TV receiver's audio control to middle range and note how 'loud' the sound is. Make sure there is normal talking, not a quiet scene or loud music, on the air. Now switch to the modulator channel and attempt to match the two, to your ear. Not very professional, but you can get to within 3 dB of audio level to the local station in this way. A videotape machine as a source will also work if you are minus a local signal.

If your TVRO receiver has **its own** audio output level control (i.e. DX DSA series) **and you also have** a modulation level control on the modulator, you have two controls to work with. Some modulators are

very sensitive to too much audio **drive;** that is, too much audio signal **coming from** the TVRO receiver. Therefore, when you run the adjustable audio level control way up high or maximum on the TVRO receiver, you may find that you have to but barely 'crack open' the modulator's modulation control to get the proper audio level. **That is a mis-adjustment** since you may overdrive the input circuit on the audio side of the modulator in doing this. The result will be proper audio **level,** but some fuzzy sounding audio that may crackle, hiss or garble on high voice peaks/loud sounds. The appropiate thing to do is to compromise the two controls; set the TVRO receiver's output level control back to about half way, and then adjust the modulator audio level control to an appropiate level for 'comparable' audio levels.

The following adjustment is not recommended but we do pass it along as a skill which perhaps you can acquire. The subject here is setting the audio carrier level to something approximating the desired 15 dB 'down' level reference the video carrier.

A typical TV receiver will still recover reasonably good audio when the audio carrier is reduced below the video carrier by 20 dB (i.e. -20 dB). The same receiver will all but lose, or lose totally, the audio when the audio level is set to a level that is **25 dB below** the visual

carrier. So if you can tweek on the audio carrier level control, and turn it so that the sound **disappears** on the TV set, you know you are in the vicinity of - 25dB reference the visual carrier level. Now, marking that spot on the shaft, you can then turn the audio carrier level control fully up. At this point you will be around 5 to 8 dB below the visual carrier level with **most** modulators. Mark **that** spot on the knob or shaft. Look closely at the shaft; how much did you turn it to get from the -25 dB region to the -5/8 dB region? If you split that difference, you should be in the -15/17 dB region with the audio carrier level.

When you have the **audio carrier level too high,** you end up with 'worms' in the screen on the **next higher** (immediately adjacent) channel. When you fine tune the TV picture on channel 4, for example, you find a spot where the color is best on 4 butyou also have 'worms' crawling through the picture. Those worms would go away if you turned off the channel 3 modulator; indicating the audio carrier on channel 3 is too high and the channel 3 audio is getting into the channel 4 picture. You could then turn down the channel 3 audio carrier level to the point where the worms cleared up in channel 4. If you can also still comfortably hear the sound when tuned to channel 3

that is a good spot to leave everything alone until you get your hands on an FSM!

The danger in all of this is that without an FSM, you have no real way of telling whether you have worms in channel 4 video because the channel 3 audio is too high, **or,** because somehow the carrier levels on channel 3 are too high (or levels on channel 4 are too low). Sooner or later you will **have to invest in** a field strength meter (FSM) if you are going to play in this game.

SMATV/HEADENDS

PART 2

ALL Signals Created Equal

In our look at the SMATV headends in the last chapter, we were concerned that our modulator/channel products would be compatible with one another, and that as we added channels together (called 'combining') we would not create inter-action between channels on the cable distribution plant. Here we will look at the unique problems presented by local, 'off-air', television signals, and deal with the complex problems that come up when we are attempting to 'mix' both off-air signals and modulator-created signals into a single cable 'trunk'.

To understand how problems arise, you first must have a fundamental grasp of how the television spectrum is 'laid out', and, how the average television receiver reacts when you present it with a multitude of television channels; **one after the other on the dial.**

Channels are grouped, one after another (i.e. **adjacent**) as follows:

A) Channels 2,3,4

B) Channels 5,6

C) Channels 7,8,9,10,11,12,13

We will make reference here to 'upper adjacent channel' and 'lower adjacent channel'. That works this way.

Channel	Upper Adjacent	Lower Adjacent
2	3	None
3	4	2
4	None	3
5	6	None
6	None (FM Band)	5
7	8	None
8	9	7
9	10	8
10	11	9
11	12	10
12	13	11
13	None	12

The television receiver functions by tuning the desired channel (such as 3) and then shifting frequency of that channel (sound and picture) to an 'IF' in the 41/45 MHz region. The IF stages of the TV set are just like the 70 MHz (IF) segment of your TVRO receiver; they provide selectivity, to

seperate out a **single channel at a time,** so that the demodulated signal containing audio and video is 'clean' of any interferrence from adjacent channels.

The 'selectivity' of the TV set's IF is not very great. When the television set sees channel 3 in the IF, it will also see **part of** the channel 2 information at the same time. The TV set IF is where a considerable amount of 'signal gain' takes place, just as with your 70 MHz IF in your TVRO receiver.

As the diagram here shows, all channels which are adjacent on one or both sides to other channels have an **audio carrier just below** the desired channel video (i.e. channel 2 audio is appearing just below the channel 3 visual carrier) and a **video carrier just above** the desired channel audio (i.e. channel 4 video just above channel 3 audio).

Within the channel, inside of that 6 MHz bandwidth that a TV channel occupies with the NTSC television system, the channel is sub-divided as show in **diagram form here**:

A) The video carrier is on the lower side of the channel, actually 1.25 MHz 'up' from the bottom of the channel proper (i.e. channel 9 is assigned to 186-192 MHz and the video carrier falls at 187.25 MHz).

B) Precisely 3.58 (give or take a few thousand parts) is a color 'subcarrier'. In our channel 9 example, this places the color subcarrier at 190.83 MHz.

C) Then, 4.5 (00) MHz above the video carrier is the sound carrier. We are now at the 'top' of the channel assignment (186-192) and we are only .25 MHz away from the lower boundary for channel 10 (192 MHz).

The sound carrier from the lower adjacent channel (8 in our example) will therefore be **1.5 MHz below** the visual carrier **for channel 9;** while the visual carrier for the upper adjacent channel (10 in our example) will be 1.5 MHz above the aural carrier for channel 9. These are relatively close spacings, and this is a cause of considerable problems when you attempt to stack one channel after another on a cable system. You are asking the individual television receivers to properly tune-in the desired channel, and, to reject or ignore the immediately adjacent channels on **each side.**

Television sets were never designed, originally, to operate with immediately adjacent channels. The FCC, widely, in establishing thee 'channel allocations' pattern did not assign **adjacent channels to the**

same city or 'market'. The allocations were geographically alternated so that each successive market used the 'other' set of channels. An example:

A) New York City is allocated channels 2,4,5,7,9,11 and 13;

B) Philadelphia/(Lancaster)/(Wilmington) are allocated channels 3,6,8,10 and 12.

Between the two markets, we have all 12 VHF channels in use. But none are in use on adjacent-channel basis within a single market.

If the FCC and TV set designers never intended for there to be 'adjacent channel operation', how do cable systems get away with it?

The trick is to very-very carefully maintain an almost exactly equal or even signal strength levels on all adjacent channels going to a cable connected TV set. If a TV set receives +6 dBmV on channel 3, it must also receive the same signal level (+/- 3dB) on channels 2 and 4. The TV set **will seperate** adjacent channels, **provided** the signal levels are 'balanced' channel to channel. This is something cable can do; it is not something that indivisual home antennas can do.

When the cable system does not do this, we have two possible types of interference. The channel 8 carrier, **in our example**, if too strong in relation to the channel 9 visual carrier, will place a cross hatch or pattern

over the top of channel 9's picture. There is a proper 'minimum-level-difference', as we shall see, to be maintained between the lower adjacent audio, and the desired cahnnel visual carriers.

If thechannel 10 visual carrier is too strong, then we will have scratching sounds and 'cross-talk' from the channel 10 video onto the weaker channel 9 audio carrier. Again, there is a proper ratio or relationship to maintain between true adjacent channel carriers.

We have already established that there should be a 'leveling' between true adjacent channels; at each set connected to the system. And within +/- 3dB (or less), we must insure that the adjacent channels stay even with one another.

We also have one other consideration; the ratio or difference between the desired channel video carrier, **and its own sound carrier**. The generally accepted pratice is to adjust thedesired channel audio carriier so that it is 15 dB weaker (generally written -15 dB) than the desired channel visual carrier. If we follow this practice, then our example becomes:

1) Channel 8 audio/ -15 dB reference channel 9 visual carrier;

2) Channel 9 visual/ +15 dB reference channel 8 aural carrier;

3) Channel 9 aural carrier/ -15 dB reference channel 9 visual carrier;

4) Channel 10 visuqal carrier/ +15 dB referencechannel 9 aural carrier.

Those are the basic rules of placing channels into an adjacent channel environment on any cable system.

OFF Air Signals

In an SMATV system, we will be typically taking one or more satellite delivered signal, through an in-house modulator, and mixing the satellite/modulator signals with locally available off-air (VHF or UHF) channels. The net result will be a mixture of several possible services.

Let us assume for illustration that we will have channels 7 and 9 in our system occupied by modulator signals; and channel 8 occupied by an off-air signal. The off-air channel 8, our first example, is relatively close by and all that we require is to install a channel 8 (single channel) antenna, running coaxial cable to a single channel 'strip' amplifier.

A **strip amplifier** is sort of like an 'IF'; it is designed to amplify a single channel. However, because we have the adjacent channels so close in frequency, if there happens to be any measurable amount of channel 7 or 9 in the same area (even if very weak), the channel 8 strip amplifier would also amplify these carriers as well; in particular, the channel 7 audio and

the channel 9 picture.

If we intend to use channels 7 and 9 for on-cable distribution of **modulator signals**, we do not want any 'other' channel 7 or 9 signals in our cable system. Given that the channel 8 'strip amp' is not totally selective, we need some way to insure that only channel 8 goes through the strip amp and not into the system.

The solution to that is a unit called a 'bandpass filter'; a highly selective device that traps out (gets rid of, attenuates) any possible channel 7 or 9 signal(s) coiming through the channel 8 system. **That is shown here in diagram form.** Note that we have installed the bandpass filter between the channel 8 antenna and the channel 8 strip amp. It could also go after the channel 8 strip amp, but the usual practice is to place it in front of the strip amp to avoid allowing channel 7 and 9 signals into the strip amp at all.

If our off-air signals are not local (i.e. within 50 miles or less), we can expect them to vary in signal strength from hour to hour and day to day. In fact, even signals from a few miles away will vary in level as the weather in between you and the transmitter changes. However, we can usually cope with relatively modest changes in signal level as we shalll see.

A 'distant' off-air channel requires either a bigger receiving antenna (such as 'stacked yagi antennas'), and/or its own signal pre-amplifier. The pre-amplifier is like the LNA; it mounts typically at the antenna proper, boosting the signal before there is signal degradation (attenuation) caused by the loss of the coaxial cable between the antenna and thestrip amplifier/processing equipment.

Most of the modern strip amplifier packages either have 'AGC' (automatic gain control) as a standard feature, or it is available as an option. AGC is very important with a strip amplifier operating on any channel that is subject to signal level variations, since unless there is a method to **control the output signal leaving the strip amplifier,** we will have picture levels going up and down on the cable system as a function of the input signal level variations. Remember that our adjacent channel cable system will work, with a standard TV set, provided we maintain constant and even signal levels on adjacent channels. A channel 8 signal that goes down 10 dB in the daytime and comes up 10 dB at night is going to drive channels 7 and 9 crazy on thecable. So we must 'AGC' or control the channel 8 signal, in the processing or strip amplifier equipment. Most strip amplifiers with AGC will control a signal that

fades up and down through a 20 dB region and maintain the output to the system within +/- 1 dB. However, not all signals fade in the same manner. Some signals may fade 'down' 5 dB in the worst average case, **but up 15 dB** when the weather is just right. This means that you have to adjust the 'AGC window' of the strip amplifier so that rather than sitting in the **middle** (i.e. capable of controlling signals that fade **down 10 dB and up 10 dB**), the AGC window is 'offset' to control signals that fade down 5 and up 15. Instructions with most strip amplifiers tell you how to do this; usually strip amp controls and/or external pad units.

UHF Problems

UHF or ultra high frequency channels are typically converted to VHF channels for cable distribution. The UHF channels (14 to 83) are caoable of being cable distributed, but very few systems do it that way. The losses in the cable, at UHF frequencies, are quite high and the cable distribution equipment required not of the 'caliber' as one finds for the VHF channels.

In illustrated form here, we have there possible connection combinations to get an example channel 39 signal to channel 9. Let us assume we have a desired channel 39 but at something weaker in level a non-desired channel 42. Our UHF to VHF converter will see thechannel 39

signal and because of theconverter's design and tuning, place channel 39 on 9. The (weaker) channel 42 will show up three channels higher, coming out of the UHF to VHF converter. That places it on channel 12 and if we have amodulator (or VHF) station on channel 12 in our system, this will cause interference.

The solution would seem to be a bandpass filter. There are two options, **as shown.** We could install a UHF bandpass filter for channel 39 between thechannel 39 antenna and the input to the 39 to 9 converter, or, we could install a channel 9 bandpass filter at the output of the 39 to 9 converter. Which is best?

It turns out that you always get better stability, and better selectivity, if you keep your 'filtering' at the lowest possible frequency. This is why we have our filters in a TVRO receiver at 70 MHz rather than some much higher (gig-a-hertz) frequency. So this says that the best choice is to select a **channel 9 bandpass filter** and install it **after** the 39 to 9 converter, ahead of a strip amplifier for channel 9.

UHF signals are subject to a higher degree of signal fading (up and down levels) than VHF signals. Signals that have to travel to your location over any substantial body of water (lake, along or over the ocean) will vary up

and down far more than signals that travel over flat farmalnd. For this reason an 'AGC' strip amplifier becomes especially important when processing UHF signals to a cable distribution plant. They will also vary 'closer in' to the transmitter; often with objectionable amounts of up and down signal variation, as close as 30 miles from the transmitter.

Now that we understand how VHF and UHF channels must be treated, seperately, let's deal with an off-air package of four channels, **as illustrated.** We have channels 4 and 5 on low band, channel 7 on high band, and channel 39 converted to channel 9 on UHF.

We will also have five modulator channels. Our channel line-up will look as follows:

A) Channel 2/modulator, WGN

B) Channel 3/modulator, CNN2

C) Channel 4/off air, CBS

D) Channel 5/off air, NBC

E) Channel 6/modulator, ESPN

F) Channel 7/off air, ABC

G) Channel 9/ 39 converted to 9, off air, independent

H) Channel 11/modulator, CBN

I) Channel 13/modulator, WTBS

We'll deal here, for now, only with the off-air channelss.

Channels 4 and 5 have seperate signal channel yagi antennas. No pre-amplifiers are required because of the strength of the signals. The signals go through coaxial cable (typically RG-59/U or RG-6/U) to a bandpass filter, and then to the respective signal channel strip amplifiers.

Channel 7 is some distance so we have a signal pre-amplifier at the antenna, the signal then goes through low loss coaxial cable (RG-6/U or RG-11/U or .412 aluminum cable) to the indoor power supply that runs the pre-amplifier. Then there is a short jumper of RG-59/U cable which interconnects to the input of a bandpass filter. Finally there is the channel 7 signal strip amplifier.

Channel 39 is close enough that no pre-amplifier is required. The signal goes into a single channel UHF to VHF (crystal controlled) converter which places it on channel 9. The channel 9 signal now loops through a channel 9 bandpass filter (only required if other UHF channels might go through the converter and channel 9 strip to cause interference with other cable channels), and finally through a strip amplifier on channel 9.

FILTERING Of Modulators

We have seen how bandpass filters are essential parts of an off-air processing system. If we wish to insure that each 'single channel processing package' is, indeed, only a single channel at the output. How do bandpass filters fit into our modulator channels?

There are, generally speaking, theree 'levels' of modulators available.

A) **Level One**/the 'home style' modulator, typically operating on channels 3 or 4 (although some models are adjustable over other VHF or even some UHF channels as well);

B) **Level Two**/single channel modulators, designed for MATV system use, usually crystal controlled on a single channel.

C) **Level Three**/single channel modulators, always crystal controlled, designed for CATV use.

Level one modulators have two strikes against them for SMATV system use:

1) They have **low output power capability,** typically less than +10 dBmV which happens to be about the right amount of power for a single TV set (or two) but not enough for use with multiple sets in a cable system.

single piece of (trunk line) cable?

Let's look first at a simple system, using just low band channels 2,3,4,5 and 6. We have off-air signals on channel 3 and 5, modulator channels on 2,4 and 6. We have elected to use a level of modulator (Level Two) which does require a bandpass filter after the modulator. We are also placing bandpass filters after our two off-air channel strip amps; channels 3 and 5. Why **after** the strip amp?

There is no hard and fast rule that tells us me MUST place all strip amp bandpass filters ahead of strip amps. Here is what is involved.

If we have possible off air signals on channels 2 and 4 which **might** get into the channel 3 strip amp system, we would like to filter them out so they do not interfere with our channel 2 and 4 modulator source signals. **We can place the filter ahead** the strip amp and do this; or **we can place the filter after** the strip amp and do the same thing. The net result is precisely the same. The filter will attenuate (reduce) the level of channel 2 and 4 signals the same amount in either position.

We al the probability that regardless of whether there are any carrier signals on channels 2 and 4 that might bother us, we are going to have a modest but measxurable amount of 'noise' coming out of the strip amp's

these two questions:

1) **"Does this modulator have a lower vetigal sideband filter"?** That means does it filter out the lower adjacent channel information. If the guy responds, "huhhh?", you know he is not up on his modulators. Proceed to the next question.

2) **"Does the manufacturer recommend using this modulator** with true adjacent channel operation: can I use it on channels 2 and 3 and not have the channel 3 modulator cause interference with the channel 2 signal"? He should understand that one, or the data sheet should tell you.

Level three modulkators have built-in 'lower vestigal sideband filters'. That means they are, indeed, designed to operate in adjacent channel configuration. You can stack them up all day long, and combine them from one to another in a prescribed manner, as we shall see.

COMBINING Channels

Now we have two seperate types of signals in our system; we have off-air signals which wee have processed with the appropriate filters and strip amplifiers and other required equipment, and we have our modulator source channels from satellite. How do we get them all together into a

2) They often send out a signal which has **two sidebands** present; an upper sideband **and** a lower sideband. **You need and want** the upper sideband (the part that falls in the channel from the visual carrier upward, higher in frequency; **see diagram** on page **XX** here). You do not want the lower sideband since it falls down below the carrier frequency, into the next lower (adjacent) channel.

Level two modulators are permissible for SMATV use **provided** you do not usde them with any lower adjacent channels. They typically do have sufficient signal output (although not as much as the CATV versions), but they also typically do not have a 'filtered' lower adjacent channel.

This means that you could use them on channels 2, possibly 5 and 7 un a 12 channel system; or any other channel provided you were **not using the channel immediately lower** (i.e. use it on channel 3 when channel 2 will be vacant).

Or, you could use this type of modulator **and** you could install a **bandpass filter** after the modulator. The bandpass filter will take out the unwanted lower sideband signal, and that will eliminate the 'double sideband modulator' causing interference with the lower adjacent channel.

You find out what type of modulator is being offered you by asking

innards on channels 2 and 4. Noise is a form of interference, and we can eliminate or greatly reduce it if we simply place a strip amp bandpass filter **after** the strip amp. In other words, even without adjacent channel 2 and 4 signals, we can always get a cleaner signal through a strip amp if we follow it with a (high quality) bandpass filter. So by placing it after the strip amp, on channels 3 and 5 in our example, we have cured two potential problems; whereas, if we placed it ahead of the strip amp, we would cure only one potential problem.

Most strip amplifiers have something called 'loop through'. We'll see what that is all about, shortly. Loop through does not work, however, as a 'tool' for the headend wiring technician if he has a bandpass filter **after** the strip amp. Strips 'loop'; bandpass filters typically do not 'loop'.

To combine our five channels, we have to 'mix' them together in a precise manner. We have the following rules of thumb:

1) We never connect two immediately adjacent channels together at the same time.
2) We combine in 'steps' or stages to insure that we do not cause interference between the channels we combining into an eventual single output line or cable.

In our example low band (2-6) system, **we have an illustration** of how this is done. The mixing or combining 'tools' are 'hybrid splitters'. We normally think of a signal splitter as a device that takes the signal source and divides it up into two or more seperate output lines. The same device also works fine in reverse; you plug the signal sources into the output, **and then the single unit becomes the output!** The word 'hybrid' is important since this describes a particular type of divider; one which allows you to use it in this type of application. When in doubt, ask to see the specification sheet. A non-hybrid splitter will not function properly in this application (and it is a bad choice for normal splitting applications as well).

Channels 2,4 and 6 are individually connected to the three **outputs** of a three-way hybrid splitter. Channels 3 and 5 are individually connected to the two **outputs** on a two-way hybrid splitter. Now we have to get these two sets of signals together; this requires a second two-way splitter to combine the 2/4/6 **and** 3/5 lines **to a single line.**

Many of the modulators and the strip amps you will run into typically have 'loop through' capability. That essentially means that you can, in a proper sequence, connect up the various channels by looping a set of cables

from one modulator or strip amp to another modulator or strip amp. This eliminates **some** of the external hybrid units.

See the '**Master Combining' example here**; using channels 2, 34, 4, 5, 6 plus 7, 9, 11 and 13. We have strip amps on 4, 5, 7 and 9; the balance are modulators, as in an earlier example.

Using the 'loop through' fittings (two on each unit) we start with the channel 2, 4 and 6 set. It does not matter that one of these (4) is a strip amp and the other two (2 and 6) are modulators. We always loop from low channel to high channel (i.e. start with 2 and loop towards 6). Since channel two has a pair of fittings (two 'looped output' connectors), and we are starting here, we have to do something intelligent with the **unused** channel 2 fitting. We cannot simply leave it alone; that would provide an impedance mis-match to the system. So we insert a 75 ohm resistor, installed inside of an 'F' fitting, into one of the two channel 2 'loop output' fittings. This effectively '**terminates**' the un-used fitting. Now we take RG-59/U cable and loop to 4. Then a new piece of cable from the second loop output fitting on channel 4 to either of the two fittings on channel 6 (they **may have** an arrow next to the fitting indicating which is the 'input loop' and which is the output loop). Now we have one fitting, on channel 6,

left over. We'll return to it.

As the drawing shows, next we terminate one of the channel 3 loop fittings and connect 3 to 5; then follow the same procedure with 7, 9, 11, 13; always starting (with a terminator) on the lowest channel number and moving upward to the highest channel.

The combining sets are as follows, in a 12 channel system:

1) Set one: channels 2, 4, 6 in that order;

2) Set two: channels 3, 5 in that order;

3) Set three: channels 7, 9, 11, 13 in that order;

4) Set four: channels 8, 10, 12 in that order.

There will always be a terminator on one of the two loop fittings on the lowest channel number in the 'set' (channels 2, 3, 7 and 8 in our 12 channel example), and at this point you will have an unused fitting on channels 6, 5, 13 and 12.

Now we take a pair of two-way hybrid units and we further combine the 2/4/6 and 3/5 sets; and another two-way hybrid and combine the 7/9/11/13 and the 8/10/12 sets, if in fact all are being used.

In our example we do not have any 'set four' channels in use so we end up combining the two low band sets in one hybrid and now we have two

sets left to combine; **the low band channels** and **the high band channels**. You have an option here; you can use another two-way hybrid combiner unit, or, you can select a device called a 'high/low splitter'. The combiner (splitter used backwards) is self explanatory. **What is a high/low splitter?**

As we are about to see, all hybrid splitters, used as signal combiners, have 'loss'. That is, you lose signal in combining just as you do in splitting. Naturally you would like your headend output signal level, to your SMATV/CATV trunk cable, to be as strong as possible since the stronger it is, the further you can go in cable before re-amplifying the signal. Therefore you will look for techniques to keep headend 'combining losses' at a minimum.

The high/low splitter is a slightly lower loss device that a straight two-way splitter. It has a set of filters inside which allow the low band channels (2-6) to pass through one side and another set of filters which allow the high band channels (7-13) to pass to the other connector. Rather than having nearly 4 dB of splitter or combiner loss, the losses are in the 1 dB region. Again, the key word here is 'hybrid' whether you are purchasing a splitter **or** a high/low splitter.

LEVELS That Lower

Because the name of the game is to make all of the respective channels turn out at about the same signal strength level on the customer's television set, and because we have a number of factors within the cable lsystem working against that goal, we have to do what we can to get as much signal as possible out of the headend, in a single piece of (trunk line) cable.

An Illustration here shows what we are facing with a 12 channel system. We are ignoring whether the channels are modulators or strip amps at this point; it really doesn't make any difference to the system.

A quick lesson in the fundamentals of cable plant signal levels.

1) **All clable has signal loss**; that loss increases as the frequency (channel number) goes up.
2) **Higher numbered channels will end up weaker**, at the end of a given length of cable, that lower numbered channels.
3) One partial solution to this is to 'tilt' the output of the headend, so that the higher channels leave the headend with greater strength or power.

This is reflected in the illustration here where we have 12 operating

channels.

Note that we are combining sets just as previously discussed; 2/4/6; 3/5; 7/9/11/13, and 8/10 and 12. Start with the channel 2 output; +43 (dBmV). Drop to channel 6; +45 (dBmV). More dBmVs means more (stronger) output signals from the strip amps or modulators. Notice the high band channels (7 through 13). Channel 7 has an output of +50 (dBmV) while channel 13 has an output of +52 (dBmV).

There is minimal loss when channels are combined through the 'looping connectors'. Now we have to get the four 'sets' of channels combined further and this requires external combiner (splitter) units, as shown.

Each time we combine two sets, through a two-way unit, **we lose 4 dB**. As you can see on the 'output side' in the illustration, we have reduced the respective levels (channels 2 and 6, 7 and 13 are shown) to allow for that combining loss.

Now we have the low channels together, and the high channels together. Which leaves one final combining operation. The illustration shows a high/low combiner which if it was another hybrid unit, would be an additional 4 dB of 'loss'. This then gives us our final signal levels to feed into the trunk cable; the line that will carry signals to the cable

distribution system and the subscribers. The output to the trunk, and this is important, is now +35 (dBmV) on channel 2 and +44 (dBmV) on channel 13. Assuming the 9dB of 'tilt' (the difference between 2 and 13) is correct for our system, that, then, is the total amount of signal voltage we have for the actual trunk/subscriber line. **We lost 8 dB** in the combining process; **not an inconsequential amount**.

At this point we are ready to sit down and design the cable distribution portion of the system.

TEST Equipment

If you are new to the cable distribution business, you should be starting to get the point that at least a minimal amount of test equipment is essential. **Setting signal levels** at various points is crucial. **Knowing signal levels** at other points is critical. You cannot simply plug in a television set and gaze at the signal.

There are three basic test equipment tools for the SMATV system installer:

1) A field strength/signal level meter;

2) A spectrum analyzer, and,

3) A decent television set.

The one absolutely essential tool is a signal level or field strength meter. What is it?

Signal level is measured by a basic increment of voltage called a **microvolt**. A microvolt is 1/1,000,000th of a volt. Not very much voltage. It takes around 1,000 microvolts to produce a first class color television picture on an average TV set. 1,000 microvolts can be fractionally reduced to a more convenient number called 1 millivolt. A millivolt is 1/1000th of a volt. Still not very much signal.

Dealing in microvolts and millivolts is a pain in the neck. So the cable industry adopted a 'transfer medium'. Microvolts and millivolts are difficult (or tedious) to add and subtract; especially when you get into planning or laying out a cable television distribution plant and you **must** do some signal level versus attenuation **calculations** for each part of the system.

And so, in the early 50's, the cable industry adopted a rather nifty system worked out by the people at Jerrold (now G.I.). They took the various microvolt and millivolts readings and using a system originally conceived by the audio engineering people, assigned a dB 'value' to the signal level which all TV sets require for a 'perfect picture'; **1,000**

microvolts (or 1 millivolt) **became 0 dBmV**. That means 0 (no) decibels above (more than) 1 millivolt (mV).

0 dBmV is not **no signal**; it is the amount of signal a television set needs to have to make pretty pictures. Anything lower than 0 dBmV (or lower than 1,000 microvolts) instantly told the technician he had a 'low signal level problem'. Anything above that was good; provided it was not too far above it!

For now, understand that it is a quick and convenient way with a signal level meter (SLM) to know where you are in a system design and operation.

A signal level meter (they used to be called 'field strength meters' in the old days; we'll call them signal level meters or SLMs from here on) measures those dBs (microvolts). Most SLM meter scales read out directly in dBmV notations and a few still retain a second scale in micro or milli volts as well. There are SLMs from just under $100 (typically designed to read just a few signals, such as channel 2 and 13 since those are the most important two in a typical 12 channel system), to well over $1,000. They read out in analog (meter movement scale) or digital (digital display). We'll review some of these on the market before we get all done.

Here is **where** you need an SLM, just in the headend.

1) **Off air signals:**

A) To measure how strong it is,

B) To see if you have objectional signals on adjacent channels which might leak into your system, without bandpass filters.

C) To adjust the output level of a strip amplifier (all have output level controls).

D) To adjust the AGC 'window' (see page **xx** here) of a fancy strip amp.

E) To adjust the sound to picture carrier ratio (see page **xx** here) for that channel.

2) **Modulator channels:**

A) To set the output level of the modulator.

B) To adjust the sound to picture carrier ratio of the modulator.

C) To check for strong harmonics or other problem signals coming out of a modulator, capable of causing interference to other on-system channels.

Once the system is wired up, that is you have all of the channels combined, you will need to have a 'test point' at the headend. This is

simply a spot where you can plug in your SLM and determine accurately the signal level to and on the trunk cable line. One of the better ways to do this is to install a device called a Directional Tap in the trunk line at the headend. It can install between the output of the last combiner (high and low channels together) and the input of the actual trunk cable line.

A directional tap is a device used within the cable system to 'siphom off' just a prescribed amount of signal to the individual subscriber 'drops' or outlets. By installating on at the headend, you have a safe and secure, interference free spot to plug in an SLM and/or a television set to check both the signal levels and the signal quality as the signals head into the trunk of the cable system.

Then there is the spectrum analyzer. An SLM is a tunable device; it tunes **one** TV channel and **one** TV carrier **at a time**. With it you can tune in the picture carrier for a channel, measure its level, and then turn the dial and tune in the sound carrier level for the same or next channel. You can go through every carrier on the ssytem and measure how strong each one is; and that is important. But, you must do this one carrier at a time.

Normally, this is not as slow as it might seem and it is an adequate

system since you seldom have to stop and check **every** picture and **every** sound carrier at **every** location. That's why they sell 'installer SLM' units for around $100 that spot check just channel 2 and 13; by checking the two 'extremes' (lowest and highest channels) in a system, you can be quite sure the system is functioning properly (or not properly).

However, there are times where a more advanced instrument that gives you a visual, scope screen display, of more than one carrier (or channel) at a time, is very-very handy. They call this unit a 'Spectrum Analyzer' and with such an unit you can actually 'see' on a display screen each of the carriers in a channel (including color, which is almost impossible to detect or measure with an SLM), or on several channels, or indeed the whole spectrum from 2 through 13, all at one time.

The scope screen display (to be discussed) is calibrated up and down in actual signal level, so it allows you to not only see the carriers but to measure how weak or strong they are. The width of the screen is adjustable so that you can dial up a display of anything from one carrier, to one channel (3 carriers/picture, color, sound) to a group of channels (2-6,7-13), or **all of the channels** on the system.

As you might suspect, a spectrum analyzer is not cheap. They begin in

the $2,500 region and go up. But for a professional doing daily SMATV work, it is an almost indispensable tool; at least for the top engineer in the company.

Because of its method of display, a spectrum analyzer is also very handy for checking out 70 MHz, 270-770 MHz TVRO IF systems. The analyzer does not care whether a signal is FM or AM; it displays either equally well. The signal level meter, on the other hand, will not properly 'decipher' an FM signal and although it may tune in the 'frequency range' of the TVRO IF signal, you cannot get accurate or repeatable real level readings with an SLM of FM TVRO signals.

SMATV

Part Three

THE CABLE CONNECTION

GETTING TO Receivers

While the primary technical goal in any SMATV system is to provide a number of high quality, 'exotic' signal services which people are willing to pay money to have in their homes, the job of producing the signals to a high level of technical perfection is hardly over once the headend has been designed and constructed. Having a clean set of channels at the output 'test point' at the headend is only half the battle; **keeping the signals clean** all the way to the subscriber's TV receiver is the other half.

In parts one and two, we have looked at a broad overview of the SMATV system, and in some detail at the last lash-up required to carry both satellite delivered isgnals as well as terrestrial signals in some mixture to subscriber sets. We will concentrate on the preliminary aspects of the cable television distribution system in this segment.

Cleaning up the signals, if off-air, cleanly and cleanly modulating the signals to standard RF TV channels at the headend insures that you have a high quality product to work with and distribute. However, there are

many dangers between the output of the headend and the input to the subscriber TV set(s). It is entirely possible, even probable, that if you do not pay attention to good RF 'distribution' techniques, you can and will 'lose' everything you gained at the headend on the way to the TV set. Let's see why.

1) To connect the headend signals to the subscriber TV sets, we have to install some cable. The cable itself has **one unavoidable characteristic** which we must design around. **Loss.** All cable has 'loss' which is another way of saying that as you carry signals further and further from the headend, towards subscriber receivers, these signals will get weaker and weaker and weaker.

2) To travel from the headend to the TV sets, we mus pass through a number of 'passive' components. A cable connector is a passive component. So is a 'line splitter'. And a 'signal tap-off-unit'. **Any device inserted into the line,** between the headend and the subscriber, **can upset the flow of signal.** All devices, including connectors, have some measurable amount of 'loss'. They, like cable itself, 'resist the flow of RF signals' and where there is 'resistance', there is loss.

3) You seldom travel from the headend all the way to the subscriber's

receiver in just one continuous length of the same cable. You may travel part of the way in a 'trunk cable' (typically 1/2 inch or 3/4 inch in diameter), another part of the way in a 'feeder cable' (typically .412 or just over 4/10ths of an inch in diameter or, 1/2 inch in diameter), and then a final distance in a 'drop cable' (typically RG-59/U, RG-6/U). Each of these cables has its own 'loss factor' and each time we 'transition' from one size cable to another size cable we have some type of 'transition fitting' or passive device between the two non-compatible cable 'sizes'. Each of these devices contributes loss (some of which is on purpose, as we shall see) because each has its own 'resistance factor', and between two cablesof different size we have two different 'amounts of loss' per unit of distance traveled.

4) Unless the cable plant is very-copmpact, the amount of signal 'power' available to us from the headend modulators and signal processors is far too low to cover the 'distance' we require to get to each television receiver in the system. This means that at one or more locations along the way, someplace after the headend but before one or more of the subscriber locations, we will need to install a 'line amplifier' device. Such a unit is designed to amplify

all of thechannels on the system **at the same time** (unlike the headend where each channel is processed and amplified **individually**). As you might suspect, it is possible to have 'inter-action' in such an amplifier and we must be certain that the amplifier does not operate outside of its 'operating/gain range' if we intend to keep that inter-action to a minimum. Such inter-action shows up on subscriber television sets as a 'film' or series of oscillating lines on the screen on one, some or all of the channels. We'll see how we avoid this happening.

5) Finally, TV sets are themselves capable of creating interference to other TV sets attached to the same cable distribution system. We avoid this by electronically 'isolating' each television set, making sure that no matter what type of interference the TV set might 'generate', that interference is not allowed to crawl 'back' into the cable master distribution liens where it can cause cruddy pictures for other subscribers to the system.

TWO Parallel Systems

If your SMATV distribution system can be 'RF powered' totally from the headend, by the available signal power that originates from the modulators and/or individual channel processors, you will need no 'line

amplifier' in the system. This does not relieve you of the obligation to be careful with the design and installation of your SMATV system, since we still have cable and psssive device losses to consider, as well as maintaining each television receiver 'in isolation' from all others on the system.

If your SMATV system requires one or more 'line amplifier' units, to insure that the RF power levels for each channel on the system stay strong enough to deliver high quality pictures to the subscriber receivers (at the ends of the system, furthest from the headend), then we are in the 'dual system function' business.

Most 'line amplifiers' are solid state (i.e. all transistor) units, and they operate from an **AC operating voltage** of either **30 or 60 volts** (nominal). There are stand-alone line amplifiers also available which have their own internal 117 VAC power supplies. The advantage of the 30/60 volt units is that as you layout your system you can spot or locate an amplifier where it is required for amplification purposes alone, **without regard to whether you happen to have a convenient source of 117 VAC nearby**. How is this possible?

In a 30/60 volt AC powered unit, theoperating voltage/power for the line amplifier can be (and is) transmitted through the same coaxial

cable, the same fittings and even the same 'passive devices' such as taps, as the RF signals. In other words, the coaxial cable plant carries the AC operating voltage. Here is how that works.

Modern CATV plants neak up and down alleyways and streets where the pole lines (or buried cable lies) mandate. Getting AC power to each and every amplifier station, through dedicated AC power 'service drops', would be exceedingly expensive. Since it is technically possible to 'duplex' an AC 60 cycle voltage ontp the coaxial cable, and allow the cable to transport the operating voltage, this means that the cable amplifiers can be virtually independent in location to the source and availability of AC operating voltage. We'll see why that is important, above and beyond the costs involved in providing a seperate AC (117 VAC) service drop to each amplifier location. Why 30 or 60 VAC?

In most towns and cities, it is **not legal** to transport or carry 117 VAC around town unless you are the power company. Then, strict safety rules apply. The National Electrical Code, which most towns and cities follow and have adopted for their own, specifies that if there is an AC operating voltage of **61 volts or more** being transported anyplace along public thoroughfares, the person or company doing the transportation must follow strict electrical safety codes. This costs money. So CATV

line amplifiers have been designed to operate just 'below' the 61 volt ceiling that applies in most areas. Some systems, for design reasons, drop all the way to 30 VAC.

A 'CATV Power Supply' is a large metal box that installs on a pole where normal 117 VAC 'service drop' can be connected. The coaxial cable, originating at the headend and heading towards some extremity of the community, plugs into the power supply box and then loops through that box and comes back again. The RF portion of the service on the cable coming into the power supply box has the TV channels operational; these TV channels simply flow through the CATV power supply box with only a minimal amount of disturbance.

At someplace within the cable plant, such as at the amplifier just ahead of the power supply proper, the flow of power coming to the box from the headend direction has been 'stopped' by an adjustment within the preceding amplifier. Power to run the last amplifier ahead of the power supply has come to that amplifier from another power supply location. But from the power supply location onward, towards the ends of the system, this (new) power supply provides AC operational voltage for the amplifiers that follow. **We diagram this here.**

Our preoccupation with powering of amplifiers is at this point

illustrative; we'll see what is involved in the 'engineering side' before we get done. It points up that there are really two, parallel, functions going on inside of the coaxial cable at the same time. **Number one,** we are transporting and amplifying the broad spectrum of TV channels going to the subscriber homes. This requires certain engineering considerations. **Number two,** we are transporting an AC operating voltage of the 'active' (i.e. amplifier) equipment required along the way. And this requires another set of engineering considerations. We end up planning, designing, building and operating two 'parallel' systems that just happen to share the same coaxial cable.

THE RF Portion

Whether we elect to make use of individually powered line amplifier (i.e. those with their own internal 117 VAC supply) or we luck-out and require no line amplifiers at all, or, we decide to come back later and look at the powering considerations, we usually start off our system analysis by worrying about getting the TV signals to the subscriber locations.

1) **Cable loss increases with operating frequency.** In part one, we touched on the fact that as thee operating frequency (i.e. TV channel number) increases (i.e. 7 is greater than 2, 13 is greater

than 7), so too does the ;loss factor' of the coaxial cable. This is an important consideration since the 'resistance' of our cable to the passage of the TV signals must be carefully calculated as we plan, on paper, our distribution system.

The general approach to this part of the problem is to look at the **total length** of the system, from headend to the final, last (most distant) subscriber 'service drop' (i.e. tap off). This will be the TV set to get the least amount of signal, or, alternately to require the greatest cumulative amount of 'line amplification' between the headend and the TV set. **A representative** (small) **system is shown here.**

Just as cable losses increase with frequency (operating channel number), so too does the cable loss increase with reductions in cable diameter (i.e. size). One-half inch diameter cable, for example, has far less loss than RG-59/U cable; at both TV channel 2, and at TV channel 13 if you compare one cable directly with the other.

This is why when you isntall a TVRO system the receiver manufacturer will specify to you a 'maximum safe distance' which you can transport or carry the signal coming out of the downconverter to the receiver (modulator) proper. The manufacturer of the TVRO receiver system has calculated how much signal loss (i.e. resistance to RF) there

is, at the IF output frequency of your downconverter, with various types of cable. He may tell you that **if** use RG-59/U cable, you can have as much as 400 feet between the two units, for example. He will also tell you that if you go beyond his suggested maximum, that you should use a larger cable (one with less 'RF resistance' or loss). This is also why those block downconversion receivers LOCOM, Anderson, Janeil, AVCOM, Etc.) which use a **higher IF** frequency (typically in the 200-900 MHz region), or the DX receiver which use a very high IF in the 900-1400 MHz region do NOT allow you to use such lengthy runs of cable from the downconverter to the demodulator; **higher** (IF) **frequencies mean greater cable losses** ('RF resistance').

Therefore, the usual practice in making a rough calculation of the 'system loss' between the headend and the furthest 'customer drop' is to take the highest TV channel frequency (such as channel 13) top be used on the system, and to compute the losses at that channel to see just how much 'total loss' you will have at the ends of the coaxial cable line. If you can safely 'get there' at the highest channel, starting with the amount of signal you have available at the headend 'output' point, you know that the lower channels (with lower cable losses) will get along just fine.

All cable manufacturers can supply you with 'loss charts' or tables. These tables/charts reflect the loss per increment of cable length (such as 100 feet) at a specified operating frequency (i.e. channel). If you are considering cable which does not have 'guaranteed loss' nubmers available, move on; you are shopping for the wrong cable! And you cannot plan a system around a cable which you know nothing about.

The subject of cable loss is a detailed one, and we;ll touch on it briefly here at this time.

A) Cable loss is a function of the following factors:

1) The **size** of the cable, which really means the diameter;

2) The **composition** of the cable, which really means 'is it copper' or 'is it aluminum';

3) The **design** of the cable, which means is the braid (outer metallic portion, just under the rubberized weatherproof cover if the cable is 'flexible') very tightly packed (few if any 'air holes' in the 'weave' of the braid) or is it 'loosely packed' (which means is the braid only covering a portion of the cable's inside diameter). **Cable is rated** in 'percent of cover' for the braid (typically in the 50-70% 'coverage' area), or it is a double type of braid cover with a segment of copper (or aluminum)

woven braid **over the top** of a tightly wrapped 'foil' which looks for the world like the same stuff you find inside of some of the cigarette packs.

We've already touched on diameter; the outer distance straight across the cable if you look at and measure a 'cross section' of cable. Bigger is better, usually. We'll return to this.

Virtually all of the 'electrons' that make up the flow of the RF signal travel pretty much on the 'surface' of the cable's inner conductor. That means that like water running down a stick, very little of the electrical (RF) energy penetrates into the center conductor proper. If the center conductor is copper, solid copper, you have a relatively expensive 'electron highway' and only the 'outer lane' is used. For this reason, most cables are available with either 'solid copper' center conductors or 'copper coated/plated' center conductors. The difference is in dollars, and perhaps installation ease; seldom in performance, provided the copper plating/coating has been applied properly.

Totally aluminum center conductors, no copper plating/coating, are chaper (and franly difficult to find). They are also far more 'lossy'; they have a 'higher resistance to the flow of RF' and they are therefore to be avoided. Aluminum is not as good a 'conductor' of electricity as copper

so we elect to use copper or copper coated cable.

We mentioned the 'center' conductor. Cable has two conductors; a 'center' conductor and an 'outer' conductor. RF is nothing more than fancy electricity mnoving at a very fast frequency. You do not attempt to send electricity through a single conductor wire; you must have a second (return) wire to re-connect the device being powered or connected back to the origination point. Electricity, even RF electricity, 'flows' from source to 'load'; and in theory, 'back again'. The center conductor gets thesource and the load connected together for the outward bound flow; the 'outer' conductor or 'shield', as it is also called, connects the two together for the return process.

The shield does more. It is called a 'shield' because it also protects or 'shields' the center conductor from contamination; electrical interference to the TV signals. The air conditioners you pass by, the electric toothbrush in apartment 208, even the electrical lines in the project. The shield acts as a 'barrier' so that these interference sources cannot 'leak into' the cable TV lines and cause interference to the TV signals. A '60% braid shield' means that **40% of the center conductor area is** not **shielded;** not protected. That's bad news since the 40% 'open' can allow plenty of 'RF contaminants' to flow into the coaxial cable

and get into the center conductor. The center conductor, improperly 'shielded', is nothing but a gigantic 'wire antenna' looped all over a project or community. That's why **high braid shield percentages** are almost mandatory. Thye keep pollution out of the coaxial cable.

This is one of the reasons why the aluminum jacketed CATV cables are so popular. The aluminum jacket is a **100% shield**. It is like a piece of tightly installed 'conduit', fitting perfectly tight around the insulation material which seperates the center conductor from the outer jacket (shield). Nothing can get through THAT shield unless the shield is cracked or broken or 'wounded'!

It is woth noting that we have the same problems between our TVRO downconverter and our indoor demodulator when it comes to cable 'selection'. If your TVRO IF (the frequency at which the signals travel from the downconverter to the indoor demodulator) is 70 MHz, and you select a tupe of RG-59/U (or RG-6/U) which has a 'poor percentage of braid', you are inviting RF contamination to 'leak through' the shield and onto the center conductor. Noise from fence controllers, static from fish tanks, buzzing from fluorescent light starters, even a local TV station in the channel 2-5 operating band (which corresponds to the normal IF bandwidth of 55-85 MHz, centered on 70 MHz) can 'leak into' your cable

and create interference hwich the indoor demodulator cannot clean up. Always ask for either a braided cable in **90% up region,** or, select a cable that has both a woven braid AND a tightly wrapped 100% foil braid. This is no place to skimp on your installation!

There is one more cable consideration. Between the center conductor and the shield condustor, we have a form of insulation. The best insulation in the world is 'air'. Pure, **dry,** air. Unfortunately, nobody has ever figured out how to 'suspend' a center conductor inside of a 'shield' in pure, dry air without some form of 'spacer device' to keep the two apart.

Keeping the two from 'touching' one another is not enough (although if they do, you have a 'cable hsort' and all electrical flow stops at that point!). The cable has something called 'impedance'; a fancy term that means the cable has a characteristic which is important to the efficiency of the cable itself, and, to the transfer of energy into and out of the cable at either end. The 'impedance' is a fairly complicated parameter which depends, among other things, on the precise positioning of the center conductor and the shield. They must maintain a certain, carefully worked out, distrance from one another. If the center conductor 'wanders' inside of the shield, from side ot side close to first one wall and then another the 'impedance' of the cable goes to heck in a

hand basket, in a hurry. That's not good.

So cable scientists have created a series of chemical formulae to make up compositions which are rigid, lightweight, and not 'lossy'. Loossy?

Remember that the best 'insulator' between the two conductors would be dry air. Not wet air; dry air. If wet air is worse than dry air, would not also **wet something else** be worse than a dry something else? The answer is yes. And that means the insulator product, whatever it is, must be dry, and stay dry, even when it gets wet!

'Foam' insulation is partly air, and partly some sort of chemical. The higher the percentage that is air, the better the insulating qualities, and, the lower the 'loss' of the cable. A sponge is a sort of foam. A sponge collects and holds water. A sponge would be a poor choice for the insulator. Plastics to the rescue; some types of plastic stay rigid even when half of their diameter is replaced with 'bubbles' of air. So we have cables which are manufactured using 'solid insulation', and, 'foam' insulation. Some of the fomaier-foams play on words and call themselves 'air dielectric'. Dielectric is the fancy word that describes the insulation material. Air they are not; **part** air, perhaps.

Foam dielectric cables usually cost more than solid

dielectric cables. That may seem odd since if you take away a substantial percentage of the insulation material and replace it with (free) bubbles of air, you would think the cable would cost less. Not so. To manufacture a quality cable with precise little bubbles that don't happen in the wrong spot (such as all at one time in a clump, which would leave the cable unsupported and capable of weaving over and touching the outer shield) is quite a trick. It costs more money to 'inject the air' that it does to create a cable that has a solid dielectric; even if the solid one has more material in it.

So the ideal cable we are looking for has the following properties and mechanical considerations:

1) It has low **loss**;

2) It has good **shielding** properties.

Are there other considerations? Yes indeed; several in fact. And they are largely 'mechanical' in nature. Such as?

1) The cable has to be **weatherproof**. Remember the moisture problem; even if the insulation between the center conductor and the shield will not 'soak up' water or moisture from the (humid) air, it can still retain moisture if it gets wet.

2) The cable has to be capable of being **shaped and bent** and fondled

during the installation process. It must withstand this abuse and not 'break' or 'crack' or otherwise change shape, or electrical properties.

3) The cable should, in fact must, be compatible with some type of commonly available connector(s). It does no good to have a 'perfect' cable if you can't get or work with the connectors.

Weatherproofing. A solid aluminum jacketed 'CATV type' cable has a weatherproof cover all of its own; the solid aluminum jacket. No amount of rubber coated over the solid aluminum jacket is going to do a better job of keeping out moisture than the solid aluminum jacket. So this type of cable does not have a rubber/plastic jacket? **Wrong.**

A flexible cable, such as RG-59/U or RG-6/U (etc.) MUST have a jacket that keeps the moisture off the braid. The braid is susceptible to wanter ingress, and it is susceptible to nicks and abrasions. Both are to be avoided, obviously. So we put a tightly wrapped jacket, ribberized material or plastic, over the shield to 'hold it all together'. And to keep water and dirt and junk out.

So why would we take a perfectly good weatherproof cover such as a solid aluminum jacket and cover it **again** with plastic or rubber? Because aluminum has at least one undesirable property; it oxidizes.

Actually, it has two undesirable properties; it is also a 'soft' metal and it can easily be nicked, gouged, or chewed. A properly designed plastic type jacket can actually be tougher than the aluminum! If the cable us going to get pulled through thousands of feet of conduit, over walls, accross attics and what have you, where there lurks rocks and nails and splinters just waiting to chew into the aluminum shell, you are better off springing for the extra bucks and getting a cable that also has a plastic outer jacket. If the cable is going to used outdoors in an area where there is salt in the air (such as a seacoast town), or where there are industrial pollutants (Pittsburgh, for example) in the air, you should not use non-jacketed cable. Sooner or later the junk in the air will do a number on the raw aluminum jacket.

Bending. All cable has a 'minimum bending radius'. That means that you can make a turn with the cable, but usually not an abrupt 90 degree bend, or worse yet, fold it back on itself. Aluminum jacketed cables have an obvious problem; the jacket will kink or crease and that is not good. Why?

Remember 'impedance'; that characteristic that determines the efficiency of the cable, and, the type of equipment which the cable can interface with? And, remember that impedance is determined by the

insulation which maintains a precise distance between the shield (outer shell) and the center (inner) conductor? Well, when you kink or crease the cable, you have destroyed its symmetrical (round) shape. Now you have a chunk that is not round, and at that point (where the crease or kink is located) you have a much shorter (closer) distance between the center cvonductor and the shield. At this point the cable is no longer 75 ohms, and this will adversley affect the performance of the system beyond this point. You also run the risk with a kink of rupturing the outer aluminum shell, and allowing moisture to leak in, or signal to 'leak out',

Manufacturers of 'hard line' (i.e. that line with a solid aluminum shield) will specify the 'minimum bending radius'. They even provide 'bending tools' which are used if you are going to turn the cable's path and go in a different direction **abruptly**. When you reduce that radius, the cable begins to 'tear' at the aluminum shell and without warning it will kink.

All cable has a minimum bending radius; **even 'flexible cables.** And the reason is the same. The distance between the center conductor and shield (whether solid or braid) must be maintained; that round shape must be kept, or there will be an 'impedance bump' at that point. Even RG-59/U (which can bend back on itself very tightly) must be watched;

i.e. you cannot run it through an open window and then close the window on the cable, or use heavy hammer-in staples to attach it to a stud. Not if you will crease, or indent the cable in the process.

One of the interesting things that happens when you have multiple indentions on the same run of cable is **'trapping'**. Let's say you run a section of RG-59/U from your downconverter (or cable line) inside to a TV set. You decide to run the cable up a wall and to attach the cable to the wall you use some hammer-in staples. You get slightly carried away, not wanting the cable to slide on the wall run, and really drive the staples home. Now you have a series of indentions, places where the cable's round shape has been crimped.

Each of these locations is a spot where the cable is nbo longer 75 ohms. The combination of two or more such spots will create a 'trap'; that is, a section of cable which actually **stops the flow** of RF signals **on a particular frequency,** or frequenncies. If this was a cable drop, rather than a downconverter run, you might hook up the TV and find channels 3 and 12 were 'gone'; simply disappeared, or very much weaker than the others. You trot our to the 'line trap' and measure the signal with a signal level meter. Yup, 3 and 12 are there alright. But as the opposite end of the cable, wioth nothing in-between but cable, 3 and 12

are gone! **How can that be?**

The random selection of staple locations, the heavy handed hammer, have set up 'trap resonances' in the drop line. Channels 3 and 12 (or virtually any other single or multiple channel combination) are 'sucked out' by the unintended 'traps' made up by the crimped cable sections.

If you are running a downconverter line inside, and your IF is the normal 70 MHz (center), you **might** get away with this mistake and never even notice it. Why? Because the particular random spacing you selected for the staples created a trap or traps, alright, but the traps are 'resonant' on some frequency **other than** the 55-85 MHz (70 MHz center) range. So handling the cable, subjecting it to abuse, plays a part in cable selection. You want a cable which will stand up to normal installation wear and tear and you want you installers to be bright enough thatthey don't abuse it, exceeding normal cable 'limits'.

Connectors. It is unfortunate, perhaps, taht to use cable **you must also use connectors.** Connectors are the downfall of many technicians. They simply refuse to learn how to properly install the connectors, perhaps not realizing that the connector must have the same 'integriry' as the cable itself. The connector is an extension of the cable. It has a particular shape, a particular set of dimensions, so that it too

will be 75 ohms (or whatever impedence is required to match the cable). And it must be installed properly, following the directions created by the connector manufacturer.

Let's deal with the easy connectors first. The F-59 series connectors are those common 'F' fittings which we all use. Not all 'F' fittings are created equal; a subject we shall visit in some detail. F fittings designed for RG-59/U **foam** cable, for example, are not the right connectors to use when you have selected RG-59/U **foild-braid** cable., There are small but important dimensional differences between foam (full copper braid) cable and the foil (light copper or aluminum braid over tightly wrapped foil) cable. You can 'force' one to work with the other, but it is an operational mistake to do so. For now, let's simply be sure you understand that an 'F' fitting is not always an 'F' fitting when you grab a pack of them at the local wholesale store and head for the job. **Select the right F connector for the right cable,** everytime.

The tool to install the F connector, called a 'crimper', will also differ with different types of connectors. Some F fittings have a small, seperate metal ring called an 'O' ring which slides over the rubberized jacket and braid, and is attached to the connector proper by sliding the crimpers over the O ring and applying pressure. The O ring collapses

under the pressure, and forms tightly around the cable and the support 'ferrule' portion of the connector. This insures a tight, pressurized contact, between the cable's braid and the ferrule portion of the connector.

Other F fittings have an 'integral O ring' which simply means the ring is attached to the connector body, rather than being a seperate piece. It installs in the same manner; the crimper squashes the ring-portion for a tight, compressed fit.

Years ago all O rings were seperate pieces. Then they became integral pieces. More recently they have become seperate again (although you can still buy any of the types) and rather than being small metal rings, they are more akin to **short lengths** od small **metal tubing**. The larger 'O tubing' is desirable since it provides a larger surface area of pressure between the ferrule inside of the cable's jacket and the braid portion. This increases the strength of the connector proper (i.e. it takes more pressure to pull them apart now), and, it also makes a better electrical contact. We'll see why that is important later on.

Connectors for larger flexible cable (such as RG-6/U, RG-11/U and so on) were originally only available in 'solder-on' formats. That meant every time you installed a connector, you had to drag out a soldering iron

or gund and spend 15 minutes putting on the connector. This was not very practical when you had thousands to install, so 'crimp on' connectors were devised.. They are simply over-sized F fittings, designed to have the proper dimensional characteristics to fit the larger diameter cable. They require special tools for crimping, or a combination tool that is designed for both RG-59/U **and** RG-6/U (etc.) cables.

Connectors for aluminum jacketed cable are very specialized and there are dozens of different varieties. They look like plumbing fittings, with a body, one or more 'rings' that thread into place, compressionsealing rings and a sturdy, formal looking appearance. No two install exactly alike, but there are similarities.

1) The center conductor will be 'bared', **cut to a specific length,** and slipped into a **'center pin'** in the body of the connector.
2) One or two threaded portions that **slide down over** the bare aluminum jacket and **tighten** (with a wrench) into the body of the connector. In the tightening process, a **collapsing inner ring** digs into the aluminum jacket making a tight mechanical and electrical connection.

The connector has weatherproofing 'O' rings of neoprene or some type

of tight rubber consistency which insures that moisture does not run from outside the cable down the aluminum jacket into the innards of the connector. Most connectors come with a set of printed instructions and they must be followed. The typical tools required are a pair of wrenches, and a'tubing cutter' or other toold to carefully score through the rubber (if present) plus an aluminum jacket so you can get to the center conductor.

A word about cleaning the center conductors. To insure that the 'foam' or other insulation will not 'creep' inside of the cable, it is 'bonded' to the center conductor. In other words, as you strip or carefully cut away the isulating material between the outer shield and the center conductor, you find that tiny bits of the insulation are clinging to the center conductor. This is important in the cable's mechanical integrity, but the copper or copper-coated center conductor will not transfer energy very well **through** that last residue of insulating material.

This is true with both RF-59/U (RG-6/U, etc.) cables as well as the larger aluminum jacketed cables. In other words, you want 'clean bare copper' showing, not a residue coated center conductor. **Even with F fittings.**

The general practice is to take a small pocket knife and gently scrape

the exposed center conductor of the cable to clean away the residue. A file is not a good idea since you may file away too much and change the shape (and critical dimensions) of the center conductor. Simply scrape the stuff off and you will be in business.

And if you don't?

It is possible to 'leave behind' several 'dB' of signal at say TV channel 13, or a dB or more at even 70 MHz if the RF energy has to struggle through the residue left behind on the center conductor to make the contact to the object the fitting is plugged into. Therefore, even with 70 MHz downconverter runs, **it is wise to clean both ends of the cable's center conductor** as you are installing the F fitting(s).

Well, now we know more about cable than you ever wanted to know! Actually, we have barely scratched the surface at this point and we'll make up for it later. Because the 'highway' for our signals is cable, it IS important that you understand some of the special nuances that accompany use of cable if you are to be a successful planner and installer of any cable-type system.

CABLE Attenuation vs. Frequency

We have already learned that larger diameter cables are more efficient transporters of VHF (and UHF) television signals than smaller

diameter cables. And we know that cable loss, per incremental length of cable, also increases as the frequency goes up. Let's see some numbers.

We'll pick a set of five frequencies which are meaningful to our TVRO system and the SMATV systems we will be building" 55 MHz, 70 MHz, 216 MHz, 450 MHz and 950 MHz. And these represent?

1) **55 MHz** is the approximate carrier frequency for TV channel 2, the **lowest** TV channel in the spectrum and the lowest TV channel we are apt to carry on our SMATV system.

2) **70 MHz** is the center frequency for our standard TVRO receiving system (although some manufacturers use other 'IF' frequencies).

3) **216 MHz** is the frequency at the top end of TV channel 13, typically the **highest** frequency cable channel we will be working with.

4) **450 MHz** is the lower edge of the popular 450-950 MHz range which many of the lower cost block downconversion receiver systems (Janeil, Anderson, Locom et al) use. It has no direct bearing on our SMATV system **but** since a block downconversion system does lend itself to multiple receivers connected to the same antenna, is that not a small SMATV system 'in disguise'?

5) and **950 MHz** is the **top** or other end of the same 450-950 'block'

of channels which the lower cost block downconversion systems use.

Now let's plug in some numbers using the cable which is 'average' in performance, and which is commonly found in the marketplace.

Cable Type	**Loss/ 55 MHz**	**Loss/ 70 MHz**	**Loss/ 216 MHz**	**Loss/ 450 MH**	**Loss/ 950MHz**
RG-59/U(1)	2.5 dB	2.9 dB	5.3 dB	8.8 dB	13.2 dB
RG-59/U foam	1.1 dB	1.7 dB	4.0 dB	6.0 dB	9.4 dB
RG-6/U foam	0.8 dB	1.2 dB	3.0 dB	4.8 dB	7.5 dB
RG-11/U foam	0.6 dB	0.9 dB	2.4 dB	3.8 dB	5.8 dB
.412 aluminum	0.4 dB	0.6 dB	1.8 dB	2.6 dB	3.9 dB
.500 aluminum	0.35 dB	0.5 dB	1.4 dB	2.0 dB	3.2 dB
.750 aluminum	0.28 dB	0.4 dB	1.0 dB	1.7 dB	2.3 dB

All of the above relate to a standard length for comparison; **100 feet of cable,** less any additional losses which connectors or other passive devices in the 100 foot run might add to the cable. A special note about the first RG-59/U cable **(1)**.

Generally speaking, there is 'good cable' and there is 'not so good cable'. The not-so-good stuff sells cheaper, and if you peel back the rubberized outer jacket you will see why. Under the jacket is a braided shield. It may be copper looking, or it may be aluminum looking. If the cable has **no** 'foil braid' **under the woven braid,** and we assume here it does not, you will find the white colored dielectric or insulating material the next layer down.

The braid, as we have seen, must 'cover' the insulating material as completely as possible. Remember that a solid aluminum shield is the best (100%) coverage there is. If the braid, by visual inspection, is **loosely woven;** if there **gaps between the braided strands** which allow you to look through the braid to the white insulating material beyond, you have in your hand a poorly designed, low shielding factor cable. This cable will have higher losses and less impedance 'integrity' (i.e. not be 75 ohms uniformly) and it is not desirable even for short runs at 70 MHz.

A poor braid percentage is easy to see; the air gaps are obvious and the braid is 'tinsel' in feel and generally collapses when subject to even a small amount of finger stress. What you can't simply **look at** and 'grade' is the quality of the insulating material that seperates the braid from the center conductor.

The opposite of 'foam' insulation is a solid insulation. Remember a foam insulation is trying to inject air bubbles or chambers into the dielectric to reduce the cable's losses. A solid insulation has no air bubbles and it is tough to cut. You have no way of determining, without chemical analysis, what the insulating material is composed of. It may be anything from high grade plastic to low grade re-constituted plastic

food wrappers! Naturally, low grade plastic is to be avoided. Chances are if the cable manufacturer has skimped on the braid shield, **he has also skimped** on the choice of materials for the center dielectric insulator.

'Off brand' cable, which on inspection has a loose fitting, low coverage percentage shield, should be avoided. For any application, including 70 MHz IF runs. **Our 2.5 dB loss** number for RG-59/U **in the preceding table** assumed that we were dealing with a brand name, high quality non-foam type of RG-59/U. In the real world, you could be suckered into purchasing a roll of cable which has twice as much loss and you would never know it until you got yourself into installation problems. As always, **;Caveat Emptor'** (Buyer beware). The cable world is filled with charlatans who sell 'pretty cable' at bargain prices. It is no bargain.

Now we need to return to our basic cable plant and spend some time learning how you calculate cable losses, and that those losses mean to the planning of the SMATV/cable system.

LEAVING The Headend

As we learned earlier, after we have processed and modulated all of our SMATV system channels properly, they are 'mixed together' into a

single cable for transportation to the individual homes or receivers connected to the system. In the process of doing all of this, we ended up with a finite, measurable amount of 'RF signal power', or signal voltage, for each of the TV carriers to be carried on the system. We learned that as we 'mix' channels together, to getr them onto a single cable, we 'lose' power in the mixing process. And that when this is all done, we end up with a certain amount of signal on each channel. We also learned that we can do something called 'tilt' at the headend, to partially compensate along the cable for the differences in cable loss at our two 'extreme-end' channels; such as 2 and 13.

Measurements, done accurately with a tape measure usually, are essential in a cable plant. In a large community system or sizeable development, you can put into service a small one-wheeled machine that you roll along the ground following the path the cable lines will follow. Attached to the wheel is a footage counter and this 'Unicycle without a seat' allows you to measure as you walk.

Most developers, if you are dealing with a developer, have an accurate plot map of the property. Distances are already determined and you can use somebody else's work to layout your cable plant. A trailer park oor other 'as-built' project will have to be 'mapped' and measured by you.

First you need to determine how you will route the cable. Ideally, you will follow the same 'pathway' as the existing (or planned) telco and electrical service lines. If your cable service will be built 'overhead' (using the power/telco poles for cable suspension), their maps will be your guideline. A few words about attaching to utility poles.

There are agreements and tradition between the local power and telephone utility firms. There are also state electrical safety codes. The safety codes specify that the power service lines will be at the top of the poles, that some minimum safe distance below the power lines you can install the telephone lines. The same rules also establish the minimum 'clearance distance' between the lowest cable on the pole and the ground, or street, below. You take the height of the existing pole and you add up all of these minimum distances; 18 feet clearance, for example, from the road, and 5 feet between telco and power. That says the pole must be no less than 23 feet out of the ground, perhaps 24 to allow for the 'bulk' of the power company wiring.

Now, if a cable TV line is to be aqueezed onto this pole, it must be so located that it does not shorten the minimum distance between the lowest cable and the ground/roadway clearance, nor shorten the minimum safety distance between the power company line and the first

'communications line' (telco or cable) below it. Let's assume we have a 25 foot pole here, above ground. That tells us we have between 1 and 2 feet of 'surplus space' remaining; that cable could sneak in either just below telco or just above telco and still maintain the distances required.

If telco was installed precisely 18 feet above 'grade', the extra space on our example 25 foot pole will be between telco and power. If telco was installed precisely 5 feet below power, the extra space is on the ground side of telco.

There are something called **'joint pole agreements'** at work here; the power company and the telephone company maintain a master list of who actually pays for which pole. They attempt, in most areas (but not in all areas) to maintain a 50-50 share of actual pole ownership; i.e. who pays to put the pole in the ground to begin with. Each year they inventory the new poles added, compare it to the totals from the prior year, and 'exchange checks'. In most situations, neither one actually pays 'rent' to the other; they simply **split** the pole installation costs down the middle.

Along comes the cable guy. He is not a 'joint pole owner'; he is a renter. His service is more akin to 'communications' than 'power' so where you have a pole that is jointly owned by power and telco, the cable guy does to the telco and asks for permission (i.e. a contract) to rent pole

space. There are traditions here established over decades of 'joint pole use'. The rental fees are computed as so much, per pole, per year. Rates are subject to review by the Federal Communications Commission, and generally fall between $3 and $7 a year per pole. There is a formal, multiple (multiple!) page contract which telco will trot out for you to sign. It specifies the rental fees, the safety considerations (distances between cables) and something called 'make ready'.

PART 4

SYSTEM ENGINEERING

Once you have tossed all of these factors into consideration, now you are finally ready to look closely at how much cable you will need, and where it will run. Start with a map, locally produced by you or obtained from a utility company or the developer and locate all of your present and future potential service drops. **The headend should be located as close to the center of the project or community as possible** because of something called 'amplifier cascading'. The problem here is that you want the total length of cable from the headend to the furthest away homes to be as short as possible. You will probably use about the same amount of **cable** whether you start at one end and wire to the opposite end, or, start in the middle and wire 'out'. However, in systems where you require multiple amplifiers to reach from one side of the project to the other, you will save amplifiers if you start in the middle (so-called 'hub approach') and wire outward in as many directions as you need to go.

Each time you must add an amplifier, on a line, to 'boost' the signal, we have a measurable amount of **signal degradation.** There is something here which 'squares' in terms of interference. One amplifier

has twice as much (meaurable) interference as no amplifiers (i.e. serving every home from the headend alone). **Two** amplifiers have **twice** as much interference as **1** amplifier; **four** amplifiers have **twice** as much as **2**, 8 has twice as much as 4 and so on. Doubel the number of amplifiers and permissible levels of (cross-modulation) interference get 3 dB worse. If it takes **8 amplifiers in a line** to get **across** a project from one end, but only **4 amplifiers** in each of two seperate directions to go from the **middle** in both directions, you are better off starting in the middle. So we have yet another consideration for the system planning.

You have to 'play with' all of these factors as you plan your sysem.

1. Locate the headend, if you have that choice, so that it serves the are equally in different directions, rather than all in one direction (or predominantly in one direction).

2) Decide whether your SMATV cable plant is to use a dedicated trunk approach, or if you will allow customer service taps to be inserted into the headend output cable.

What is that all about?

TRUNK vs. Feeders

Real cable TV systems, serving whole communities, use two different types of cable plant within one plant. The premise is this,

1) While all cable has loss, and every line splitter reduces the available 'RF power' on the line by breaking it up into (mostly) even parts of 2,3 or 4, there is one device which has a profound effect on the **signal levels** on the line; **the subscriber tap-off units** or 'directional taps'. If you run a single line from the headend, and install directional taps for subscriber service on that line, you will invariably end up having to place amplifiers more often to compensate for the 'loading factor' of the taps (DT's).

2) If you isntall a 'main' cable out of the headend (called a trunk) and use that cable solely to carry RF power to the various regions within the development/community, you are able to do a better job of maintaining 'pure' or 'high quality' service to the community as a whole.

3) The trunk cable leaves the headend, in one or more directions, and it follows the 'main arteries' of the community area. The object with the trunk is to get the signal as far as possible, without amplification (or before re-amplification). Where you need to provide 'service drops' you use a unit called a 'bridger' to take a signal out of the trunk and into a secondary type of line called a 'feeder'. It is on the feeder lines where you install the DT devices

and into which the customers are plugged for service.

Let's boil that down first to a single building **system;** say a high-rise apartment building.

1) We exit the headend with a **1/2 inch trunk** cable. The trunk goes from the bottom of the building to the top floor, vertically.

2) As we pass by each floor of the building, we install a bridger unit and into that bridger we plug one or more **'feeder lines'** using smaller (.412 or 'four-twelve' as it is called) cable. The feeder lines pass down the main hallway of the floor so that they go by each apartment on the way to the opposite end of the building.

3) Into the feeder line(s) we install **Dt devices;** they 'suck out', from the feeder line, a carefully controlled amount of RF signal for delivery to the individual apartment.

4) From the DT to the apartment TV set location(s) we run a piece of **RG-59/U** cable, finally terminating the line in a matching transformer or wall outlet within the apartment proper.

If we are dealing with streets rather than a single high rise building, our system is the same; only the nomenclatures change. **The trunk runs down 'Main Street'** and at the **corners of** Elm, Oak, Cypress, Maple and Pine **we install bridgers**. These bridgers interface between the 'Main'

trunk and the 'Elm, etc.' feeders. In front of every residence or every other residence we install DTs to carry on into the house via some RG-59/U drop cable.

Then if we want to serve individual subscribers **on 'Main Street'**, we don;t plug them into the trunk; rather we 'fold back' a feeder output from the bridgers at say Elm, Cypress and Pine so that one of the bridged-feeders from each of those corner locations goes back up (or down) Main Street, along with the trunk cable, to provide customer service outlets along 'Main'. Each street has a single cable, **except for Main Street**. Where, along Main, we need to provide service to customers we place a second (feeder) cable for that express purpose.

Such an approach is 'pure' but frankly not necessary **if** you can lay out your system so that you will reach every location you need to reach within say 3 **(maximum)** amplifiers from the headend, while using the **single** (trunk) **line from the output as both a trunk** and feeder system. This one-cable, dual approach system is called a 'tapped trunk' simply because you are 'tapping into' the trunk for customer service along the way. We'll look in some detail at both approaches, and where you draw the line.

If the tapped trunk approach is 'less pure' than the full-trunk plus-feeder design, there is ar least one more design approach worth considering

which is even less pure; **a looped feeder system**. The concept here is that to save money, typically within a building such as a three or four story apartment house, you calculate how and where you will run your cable to get from the headend to the last outlet on the system. Let's say you have it figured out so that you come out of the headend with a two-way split and then go off in two different directions to carry the signal to each apartment. Your system will be within the confines of the single building, and you can use RG-6/U or RG-11/U to do all of your cabling. **You would like to avoid the cost of directional taps.**

The idea is that you will come to the apartment from the direction of the headend with the (RG-6/U or other suitable) cable, connect **into** a signal tap-off device **within** the apartment, and then **come out of** that signal tap-off device and **'loop on'** towards the next apartment. You break (or cut) the cable at the tap off device, to insert it in the line, and then carry on to the next location. You can put some finite quantity of such tap outlets in a line (series) before running out of signal.

The tap off devices typically are wall plate units, that install in standard 2"X4" wall boxes. They have a wall plate cover so that the part facing out, towards the (living) room reveals simply a harmless looking female 'F' fitting. The subscriber will plug his TV set, through an

RG-59/UU jumper, into the wall plate outlet. **Within the 2x4 box,** you bring the RG-6/U or other cable into the box from the bottom, rear or top, connect to one of the two connection points **on the back of the wall plate unit**. A second cable, leading onwards to the next identical location, connects to a second connector on the back of the wall plate unit and exits from the 2"X4" box to pass on down the line.

This sort of wall tap comes in many idfferent trade names; **Jerrold,** for example, calls them 'Ultra Taps' or DFT units, or, Omni-Taps. Each is slightly different in design but they all have the same premise; to avoid having to install a seperate, perhaps costly, directional tap device in the feeder cable line, and then run an associated piece of RG-59/U cable to the subscriber receiver.

(The primary disadvantage to the wall-plate, loop-through tap-off device is that it offers the installer less of an opportunity to maintain 'isolation' between any two television receivers connected to the same line, and less opportunity to insure that each set on the line receives a prescribed level of signal. The Jerrold **DFT** series actually includes a minature DT called a 'directional coupler', which you select based upon the signal level on the line at the point of connection. There are different values for different signal levels. The Jerrold **Omni-Tap** has a built-in,

installer accessible minature signal level control which you adjust with a signal level meter to insure that the proper amount of signal reaches each set at each location. A 'looped system' has the **further disadvantage** that you cannot (gracefully) disconnect a single subscriber from the system without **entering** the apartment, **taking apart** the wall plate, and **unhooking** the tap to the wall plug. In a situation where people pay for service, and may discontinue paying which in turn requires that you discontinue the service, this is obviously not a very satisfactory arrangement. A pure DT-fed system, with each customer service line individually accessible by the system operator is a far better approach).

Let's go back to our original pole requirements: 23 feet of vertical space between the top of electrical and the ground. And let's assume our pole is precisely 23 feet above ground; no room to spare.

Where do you attach the cable TV lines?

There are two instant possibilities here.

1) The CATV cable will be placed on an ouutrigger device called a **'sidearm'**. If you cannot get your required one foot of separation between telco and cable vertically, up and down, you get it more or less horizontally; out of the side. You, the cable operator, will pay the cost of this 're-arrangement'. If you are fortunate, the telco

will let **you** buy and install the sidearms. In some agreements, they reserve the right (under a 'make work' policy for telco employees).

2) Or, they can **'change the pole out'**. That is, to get you the additional one foot required, they put in a taller pole. Yup, you are right. That will cost big bucks and you, the guy that needs the 'space', will pay the tab. $300 is pretty common. If you happen to get onto a pole that has monster power transformers, both primary and secondary power lines, it could be a couple of grand. Obviously a sidearm is the preferred way to go.

"Make ready" really means that the telephone company, perhaps the power company as well, must make 'change outs' on their poles to get you the legal room you require. Make ready will cost you money sicne they are making ready, or room, for you. It could amount to lots of dollars.

Every single pole that you want to attach to must be inspected. You, and an engineer from the telco will 'walk' the plant and he will make notes on his plant maps as you go along. Then he will make up an estimate of the costs of 'make ready'. This will only happen AFTER you have negotiated andsigned a contract with them (they don't walk pole plants and spend engineering time on the premise that you **MIGHT** rent from them) and possibly only after you have paid them a fee to engage in this 'walk out'.

And that will happen ONLY AFTER you have a signed, legal contract with the developer or community you will be wiring. Telco is under no obligation to rent pole space to somebody who drops in off the street; only to people or firms who have some granted, legal right to provide cable TV service in the area.

Of course you could bury your cable plant. Underground. If the power and/or telco utility is already buried, there are probably no poles and you will have to go underground anyway. We will hope that you got started with the developer BEFORE he had all of his roads in and paving done. Cutting up paved roads, boring under sidewalks and using a diamond tipped concrete saw to work your way through a concrete jungle is a good way to go broke in a hurry.

A buried plant that can be 'trenched in' using a **Ditch Witch** or other shallow depth digging and burying machine **can compare** favorably to a plant that has to go on telco poles. First of all, you avoid pole make-ready charges as well as annual rental charges. Next, if you cna simply trench and bury and backfill and move on, without having to tangle with pavement and concrete, you are going to move along at a 600-900 foot clip per day per Ditch Witch team.

Obviously there is a whole study required here and our intent is not to

educate you in a few brief paragraphs of all you need to know to cope with buried or overhead cable plants. We only wish to caution you that there is more to this than simply stringing some cable from pole to pole or post to post and the 'more to' drives up the costs quickly. We trust you will take the time to study a professional operation in this business area **before** charging into any sort of 'contract' with a developer.

SMATV

PART 5

POWERING

AC BEFORE RF

If the **basic premise** of distributing RF signals via coaxial cable is now understood, we must now move onto the sub-topic of powering our plant amplifiers. Recall that the coaxial cable plant is capable of carrying not only TV (RF) signals from the headend to the subscriber locations, but it is also capable of carrying the AC operating volatage from the one or more 'amplifier power supply locations' to the cable connected amplifiers.

Coaxial cable is a relatively good grade of power cable. **If,** it is also a relatively good grade of RF cable. In other words, the larger the physical size of the conductor(s) in the coaxial cable, the better it will also be in carrying AC voltage to run our plant amplifiers. All cable has something called 'loop resistance'. It is measured in 'ohms' which is the basic unit of resistance. Cable manufacturers usually specify 'loop resistance' as so many ohms or parts of ohms per 1,000 feet. Remember that the RF 'losses' in cable are usually specified in so many dB or parts of a dB per 100 feet; and that the operating frequency or channel affects the dB loss per 100

feet.

The smaller the physical diameter of the cable, the greater the 'loop resistance' per (1,000) feet. For example:

1) RG-59/U Foam / 3.98 ohms per 1,000 feet

2) .412 aluminum cable / 2.43 ohms per 1,000 feet

3) .500 aluminum cable / 1.68 ohms per 1,000 feet

4) .750 aluminum cable / 0.76 ohms per 1,000 feet

These are nominal numbers and will vary slightly from manufacturer to manufacturer. We'll return to this shortly.

The basic CATV (SMATV) power supply provides either 30 VAC or 60 VAC to run the plant amplifiers. The power supply is housed in a weatherproof enclosure and typically mounts on a utility pole in the space between the topmost power service lines and the somewhat lower telco/cable lines. **To serve** the CATV power supply, the power utility must connect the primary or input side of the power supply to a power step-down or 'service transformer'. The power company will treat the CATV power transformer as a customer service point, just as they would a home. It may be metered (which would be read by the power company monthly so a bill can be computed), or they may accept calculations as to

the actual (constant) current load of the power supply and forget the meter; billing you for the power used based upon the calculation.

The CATV cable line, typically a trunk line although it could be a feeder line as well, comes to the power supply and plugs in. The CATV line 'loops through' the power supply and goes on. As the CATV line 'passes through' the power supply, the 30 VAC or 60 VAC (secondary) voltage from the power supply is added to (or duplexed onto) the cable line.

Here the system designer has two options. Internal to the power supply are jumper bar connections. He can elect to send AC power both ways, that is, back 'up' the line in the direction of the headend, **and,** 'down' the line in the direction of the plant ends; or, in **either direction alone.** This option is important because you cannot always locate a power supply exactly where you would like to do so. Perhaps there are several blocks where the power company does not have or refuses to make available a 'commercial power drop' to your amplifier. So you have to go past the desirable point for the power supply and in doing so, you have an amplifier or two 'back upstream' from the power supply which must be powered, as well as those 'down stream'. We look at how that works separately.

When we elect to send power in both directions, we have RF traveling

from the headend to the ends of the plant in one direction (coming towards the power supply), and at the input to the power supply we have AC going in the opposite direction. No problem; the electrons don't realize they are going backwards and since they don't belong to any union you won't have pickets out protesting.

The opposite (so called output) port of the power supply has RF going on towards the ends of the system, and AC as well. Both are traveling in the same direction in this case. **In the example shown here** we have a few amplifiers spotted to show how the RF and power flows work.

1) Notice we have a 'trunk' amplifier ahead of the power supply (left hand side of the illustration). The **RF flows** from left to right while the **AC flows** from right to left.

2) 'After' the power supply we have a 'bridger amplifier'. This is a special type of amplifier which extracts signal out of the trunk and then amplifies it in one or more output ports to connect to customer service 'feeder lines'. The bridger amp doesn't amplify the **trunk** signal (if it did, it would be known as 'trunk/bridge amp'); there is a very high quality 'directional tap' inside of the bridger which samples the RF signals present to 'feed' the 'feeder lines'. Note that

AC power flows through the bridger on down the trunk (to right), as well as out of the bridger amp at the top towards a line (extender) amplifier. The line amp is a customer (feeder) line amplifier designed to boost the signal levels on the line which customers tap into. **No power stops** at this line amp because in our example there are no amplifiers beyond this point so we have no need to send AC power beyond here. We'll see how this works, shortly.

Now one of the design criteria for the AC powering 'portion' of the CATV/SMATV plant is something called 'voltage drop'. The presmise is this:

> **Whenever AC voltage flows in wires, there is resistance to that flow from wires themselves. AC voltage** 'drop' **is similar to dB** 'loss' **in cables. Just as coaxial cable** 'loses signal' **the further the** (TV) **signals flow through the cable, it also** 'loses voltage'. **The more cable you have between the voltage source** (power supply) **and the voltage load** (amplifier), **the greater the voltage** 'loss'; **or** 'drop' **as it is known in the trade.**

Voltage drop concerns us because every amplifier in the system has

some minimum voltage level at which it will function. A number like 18 volts is common to many types of amplifiers (assuming we have a 30 VAC powered amplifier system). Therefore, we must know, in advance, how far we can carry the original (30 VAC) voltage before we end up with less voltage available than it takes to run an amplifier.

As you might guess, there are electrical formulae to help us figure this out in advance. **One of the ingredients** in calculating the voltage loss or drop is the **resistance** of the cable. And we have already discovered that cable manufacturers will tell us what the 'loop resistance' of the cable is in some increment such as 1,000 foot lengths. There is one other ingredient to calculating voltage loss or drop; the **current** being drawn or consumed along the way.

The formula first :

$$E=IR$$

If this is your first experience with electrical formulae, do not panic. This one is very basic and understanding is very simple.

There are three ingredients in any electrical circuit.

1) Current, which is abbreviated **I**

2) Voltage, which is abbreviated **E**

3) Resistance, which is abbreviated **R**

The formula E=IR tells us that the voltage (drop) in circuit will be equal to the current being drawn through the circuit (I) times the resistance of the circuit (R).

We already know how to compute or calculate the resistance; if there is a certain length of cable (such as 1,000 feet) and we know in that certain length of .500 cable there is a 'loop resistance' of 1.68 ohms, then we have a total 'R' of 1.68 in our example circuit. Now, what about the other ingredient; **the current?**

Fortunately, every manufacturer of every CATV/SMATV line/bridger/ trunk amplifier will tell us, on their data sheet, how much current the amplifier will use. That sounds easy enough; we take the current of the amplifier (say .5 amps) and multiply it times the resistance in the cable (say 1.68 ohms) and that will be our voltage drop (1.68 X .5 or 0.84 volts).

Life is more interesting than that, however.

See our illustration headed '**Calculating Voltage Drop On Trunk and Feeder Lines**'.

Here we have created a segment of a small SMATV/CATV plant. In the upper left we have the (now) familiar power supply. For simplicity, we

only show the 'output side' of the supply although we now understand that there could be another section of CATV/SMATV 'plant' to the left, on the 'input side'.

The power supply illustrated has a 30 VAC output and it has a total current capacity of 12 amps; a common type of power supply. Coming out of the power supply we have a .500 (inch) trunk line which extends 500 feet to a bridger amplifier (marked **(2)**). Following on beyond the bridger is more trunk cable which connects to a trunk amplifier (marked **(3)**) and then after 1,000 more feet of .500 cable, to another trunk amplifier (marked **(4)**). Ignore, for now, the bridged outputs feeding the 'feeder lines' out of the top of the bridger.

The IR losses (i.e. voltage drop) will be most severe to the last trunk amplifier shown **(4)**. Why?

Two reasons.

1) The cable distance between the power supply and the number **(4)** trunk amplifier is the greatest distance diagrammed. Since voltage drop or loss is a partial function of cable resistance, and cable resistance is a partial function of cable length, the more cable we have, the greater the losses.

2) In between the number **(4)** amplifier and the power supply, is trunk amplifier **(3)** and bridger amplifier **(2)**. Both of these amplifiers ALSO use AC power. They consume current and you will remember that the formula for voltage drop is a product of the resistance (in the cable) to the amplifier **plus** the current drawn **along the way**. If we have amplifiers **(2)** and **(3)** drawing current **before** amplifier **(4)**, we have two 'lumps' of voltage drop in front of **(4)**.

Now let's calculate.

On the left hand side of the illustration, we see that trunk amps **(4)** and **(3)** each draw 0.5 amps of power. And that bridger amp **(2)** draws 0.4 amps of power. We sum those current uses since they all affect the calculation for the voltage drop at/to **(4)**. That is 1.4 amps of current.

To the right, we see that the loop resistance (IR losses) to trunk amp **(4)** is 2,500 feet of .500 cable. That's 2.5 (loss is in 1,000 foot measurements, remember) times the actual 'loss' per 12,000 feet, or, 2.5 X 1.68. That is a loop resistance of 4.2 ohms.

Now we have the two elements for our equation.

E=IR, or, E=1.4 X 4.2. That works out to be 5.88 (volts). That means the voltage drop, caused by the resistance of the cable **and** the current drawn

by the three amplifiers, will be 5.88 volts. If we started out with 30 VAC, then the actual operating voltage to the **(4)** trunk amplifier will be 30.0-5.88 or 24.12 volts. If the amplifier has a (manufacturer) specified 18 volt AC 'cut off' you are safe here.

Now let's return to the other portion of this mini-system; the trio of line (extender) amps above the bridger, in the illustration. The process is repeated, with one **new** consideration.

1) The IR losses to the line amp **(7)** are found in 1,700 feet of .412 cable **plus** 500 feet of .500 cable. The losses per 1,000 feet of .412 are 2.43 so we have 1.7 (1700') times 2.43 or 4.13 ohms loop resistance.

2) We also have the 500 feet of .500 which works out to 0.84 ohms. The sum of the two loop resistances is .84 plus 4.13 or 4.97 ohms.

3) The current drain per line amp is 0.25 amps and we have three line amps. That totals 0.75 amps.

Which brings us to the calculation.

E=IR or E=0.75 (amps) X 4.97, or, E=3.73 volts.

What about the bridger amplifier? Is that not 'between' the first line amp **(5)** and the power supply? Does it not also use current? Did we

forget it?

The bridger **is** between the power supply and the line amps. The bridger **does** use current. We did **not** forget it.

How's that?

Remember that the 30 volts we are using is AC; alternating current. That means it has two parts to its cycle; a 'positive' part, and, a 'negative' part. Those clever CATV plant amplifier design engineers are created power supplies which (in our example) only use half of the cycle; they have decided (in our example) to power all of the bridger and trunk amps with the **negative half** of the cycle, and all of the line amps with the **positive half** of the cycle. That means that we can ignore the current being used by the bridger since it is not in the same portion of the AC 'cycle' as the line amplifiers. Pretty clever.

That also means that we really have a 24 amp 'capacity' power supply, in effect. We can draw **12 positive amps** and **12 negative amps** before we 'saturate' the power supply. By having one type of amplifier using the negative side (trunk/bridger) and one type of amplifier using the positive side (line-extender amps) we can better 'balance' our power load factor on the power supply.

And the voltage drop to line extender amp number **(7)?** It is 30.0 - 3.73 volts or 26.27 volts to that amplifier. Again, on the safe side of the typically 18 volt minimum for such an amplifier **(*)**.

(*) Not all line amplifiers follow this approach; check the specifications with each manufacturer before performing your own calculations.

So getting power to the amplifier equipment is no big deal. Just a few calculations and you know, in advance, how it will all turn out.

Now what are the dangers?

1) Maximum power supply capacity. All (CATV) power supplies have a maximum current handling cpaacity. 12 amps is common but there are other numbers.

It turns out that as you lay out a plant, you will usually run out of 'voltage' before you run out of current. That is, your total voltage drops will sum faster than your current loads so you usually end up either just even or slightly ahead in current as the voltage drop gets you.

2) Half cycle loading. We touched on this; you might be selecting amplifiers which power off of one, or the other, of the power cycle **halves**. It is possible to run out of negative half current before you run

out of positive half current. You must calculate the total current consumed on both halves, or the total for each half, to be sure you won't be drawing too much on one or the other.

Again, it usually turns out that you won't do this to yourself since plant layouts all fall into pretty standard designs. The exception to the rule would be if you had many closely spaced high rise buildings requiring an unusual number of line amplifiers (extenders). The 'out' here is usually that you go into such a complex from your line with a single drop and then wire that facility with its **own mini-distribution system** and its own amplifiers. Typically, you will get power for those in-facility amplifiers from the local AC service, using amplifiers which have their own 117 VAC powering system.

3) Hum bars. Anytime AC lines get upset, or somehow get crossways to your RF lines, you get an effect called 'hum bars'. That's when you have a faint white and a faint black (as in grey) bar chasing each other up (bottom to top) or down (top to bottom) on the screen. This can come from improper half cycle loading (drawing an imbalance of AC on one side or the other of the supply), from a defective power supply, or a defective filtering network in the inboard 30 VAC power

supply inside of each (or any) amplifier.

Isolate the problem. Is it occurring on all of the amplifiers fed by a common power supply? Start at the supply. Is it occurring only in a segment? Start at the first amplifier where it shows up then suspect **its internal 30 VAC supply.** Once you screw up the RF with hum bar modulation, every amplifier down stream from that point may be affected.

4) Each amp has a power supply. Remember, this is not a DC powering system. The CATV/SMATV line amplifiers **operate from** DC, not AC. But, they get their DC from the 30 (60) **VAC** source sent through the cable. That means we have a rectifier network (turning AC into DC) inside of each of the line amplifiers. Individual rectifier circuits can (and do) go bad, affecting only that amplifier. When this happens, service may still continue down stream (after that amplifier) although if the failed supply takes out the RF amplifier operation in the affected amplifier, you won't have TV **pictures** beyond that point. We'll deal with system trouble shooting in a separate part of this series.

CONTROLLING The AC

If we have all of that AC (30 or 60 volts AC) running around in our

coaxial cable plant, how do we protect ourselves and our customers from getting 'zapped'?

Remember that most states (and local municipalities) have ordinances which establish a 'voltage boundary'; anything above 60 (75) volts AC is considered a 'power distribution system' and to run wires about town with those excessive voltages on the wires requires that you act like an electric utility. That's why the cut off at 60 VAC for most CATV powering systems; to stay just under the limit.

Either 30 or 60 VAC can harm you. Especially if you are standing in a pool of water and the water is at 'ground potential'. Which is another way of saying "Don't mess around with CATV power supplies"; you can get injured or worse.

Since that AC is running up and down the trunk and feeder lines, we want to protect ourselves **and** our customers from getting jolted. Let's see how we control the AC. In the **'AC Power Control'** illustration here, we first examine how the AC inside of an amplifier is routed. The amplifier will have some system to allow you to connect up an 'AC routing line' internal to the amplifier. This may be a terminal strip with three screws, a switch with two or three positions, or a set of jumper wires or

a plug-in jumpered-module. The idea is the same in all three.

1) The AC power might come **to** the amplifier from the input connector (RF), or it might come **from** the output (RF) connector.

2) The AC power may come **to** that amplifier and **stop there** (i.e. no requirement for AC power beyond that point), or, **it may go on.**

The concept is that you can connect, for AC purposes, the input (RF) to the output (RF) in one wiring position or switch or module plug-in position. Or you can accept power from the output connector but 'block' the input connector from power; or vice versa. In the end, **you decide** which way **you want** power to enter the amplifier, and what **you want** the power to do after it gets there.

In the real world most amplifiers are powered from their input side, and, they pass power through on 'down stream' towards the next amplifier in line. The exception is the last amplifier in line; by making the appropriate connection inside of the amplifier, you 'block' or shut off AC power to the output connector.

A bridger amplifier is a special animal, as we shall see. It goes **on** the trunk but it is not (by itself) a trunk amplifier. It is actually an 'active tap'; that is, it taps or sucks some signal out of the trunk, amplifies that

signal with an amplifier and then splits that signal (typically) into two or four parts so that two or four separate 'feeder lines' can go from the bridger down to two or four separate streets in the town.

In our example, we have the trunk coming in and the trunk going out. We have elected to make this bridger the last amplifier on this segment of the plant so we have the 'jumper' connection hooked up so that the bridger gets power from the input, but does not allow it out the ouput. Then we have a pair of feeder outputs; one (top right) must have one or more feeder line amps on it since we have elected to connect the powering for that output port so that **AC will pass through**. The opposite bridged-output, upper left, has **no power through connection** telling us we will have no AC leaving through that port. The reason? The feeder line is so short that we will reach the physical end of that line before we need to install another (line) amplifier. No line amplifier; no AC power requirement.

Then there are the passive plant devices; such as the two-way splitter shown. As we will see, we may have a trunk or bridger output which must be split to feed RF signals down two (or more) streets. You find these at street corners. In our example, we have the trunk line input (left)) and two trunk line outputs. The passive (non-electronic) two-way splitter

passes the RF (after splitting) into a pair of output ports. It **also** connects the AC to both ports as well.

Now, there are splitters like this available which have **internal** power cut off connections inside; in which case if you did not wish to have AC on **one of** the two output legs shown, you would lift the top and make the appropriate connection change. In our example, we assume this is not such a unit so we have installed a **'power block'** outside of the splitter, on the bottom leg, shown. This will **stop the AC** at this point, but allow the RF to continue down the line. In this instance the RF would feed some number of homes or whatever, without any AC. In the case of a trunk, we might have another power supply feeding power back from the opposite direction at the next amplifier location on this particular leg, and to be 'double safe' with the AC system, we installed the power block so the two separate AC powering supplies can never get together even if somebody screws up at the next amplifier location on this leg. The key is a power block; a device that stops AC but allows RF to pass through.

Now what about the customer? What protects his equipment?

The directional tap device which connects into the feeder line to the home has an 'AC isolation' network inside; a miniature power block which

insures that no matter what happens, you don't get the 30 or 60 VAC service down the customer tap line to the TV set beyond. That's obviously desirable.

But there is one other opportunity for problems; **the customer's own television receiver.** That's because we have something called 'AC-DC television sets', also known as 'Gutless Wonders' or 'Transformerless Sets'.

These TV sets have been designed so that one side of the TV (metal) chassis is hot. Hot means not-warm, but active with AC. You are right; that is not very bright, but they get away with it anyhow. Even UL approves!

Given the 'right' (as in **WRONG**) circumstances, the AC on the chassis can link back out of the TV set into your cable drop line and then back into the system. Assuming this doesn't injure or kill somebody, you have a problem. The best protection is only to buy (and use) high grade matching transformers to connect your 75 ohm coaxial cable line to the 300 ohm terminals on the back of the TV set. Such a transformer has a pair of built-in miniature blocking networks designed to insure that AC that might get into the drop line side of the 300 ohm connection does not get

into the 75 ohm side. **As the illustration here shows,** the matching transformer has a 'balanced' 300 ohm side and an unbalanced 75 ohm side. The block could be on either side but we'll assume it is on the 300 ohm side for our illustration. When in doubt, ask if the matching transformers you have selected have 'AC blocking capacitors' inside. In other words, they cannot pass AC even if some happens to get onto the 300 ohm side.

Well, powering is quite a sub-subject within the CATV/SMATV planning exercise! We have touched on all of the important concerns here although this general overview is hardly a textbook, in such abbreviated form. In the next part, we will look at the RF portion of the plant and how all of those trunk, bridger and line extender amplifiers layout for maximized service to your customers, and minimized costs for you.

SMATV

PART 6

SYSTEM ENGINEERING

RF Distribution

When we last left the subject of SMATV (CATV) plant design, we had worked our way from modulators and combining off-air signals through sub-distribution systems to the AC powering system which is duplexed on the coaxial cable that carries the TV (RF) signals for distribution.

Here we will begin to look at the RF portion of the distribution plant and define some of the terminology and objectives of RF distribution.

The ideal SMATV/CATV system would connect each home to the headend facility alone; that is, the SMATV dishes, the modulators, and the signal processing equipment would be cost-effective for just a single home and that single home could then enjoy the 7 or 12 or 21 (etc.) cable delivered channels through its own custom cable system. Very few homes can afford or justify such an expense, of course, so the 'community concept' of sharing a TV distribution service was born.

SMATV is supposed to stand for '**S**atellite **M**aster **A**ntenna **T**elevision'. Private Cable means the same thing. The idea is that SMATV differs from CATV in that SMATV or private cable systems do not serve an entire

community or municipality; **it only serves a development** such as a condo group, an apartment group, or a private (non-municipal) housing development. SMATV is however, for all practical purposes, merely CATV without the legal identity of cable. As such, subject to the various court and FCC tests now being presented to this new fledgling industry, it is not a new technology. It is simply CATV on a small scale.

A single residence, outfitted with individual satellite receivers for all of the channels requested and outfitted with individual channel modulators for each of these receivers, would be a very fortunate home indeed. It would have individually processed channels, just like cable processes channels, delivered on a 'custom basis' to each TV outlet in the home. And at a considerable cost. Now let's suggest that a neighbor wishes to be connected to the system. The problem does not seem complex; the neighbor is connected to the master headend system through some more cable. Is not the neighbor's 'drop line' merely like another outlet in the primary home?

Having done that, then we have yet another neighbor, and another, who also desire the service. More cable, more outlets. Each is merely an 'extension' of the basic system serving the primary home.

Until we run out of signal.

The headend, whether made up totally of modulators (i.e. all signals are satellite delivered and the satellite receivers are connected to individual channel modulators), or made up from some combination of satellite fed modulators and off-air (VHF/UHF) terrestrial-antenna services, is your basic 'cable TV headend'. As such, you can design (as we found out in earlier parts) the output signal level(s) from the headend to be just about anything we want, within the design parameters of the equipment chosen. But sooner or later, **we will run out of signal** from the headend' because, as we have previously learned, carrying any signal through cable will weaken the signals because the cable itself has 'resistance'; a fancy term for describing the gradual weakening of signals carried through more and more cable.

We have also learned in previous segments that the cable's resistance is a function of two things:

1) The **frequency** of the signals (i.e. the channel), and,

2) The size or **diameter** of the cable.

Higher frequencies, we have learned, have greater cable resistances and therefore higher numbered channels get weaker, faster, in a given length of cable. And smaller cables have greater resistance at all frequencies (but still higher losses at higher channels) so we try to select a cable size

which balances its physical size/cost against its resistance or loss.

The most basic of all basic design problems with any cable distribution system is the cable's signal loss, or resistance. This basic problem is compounded by the wide range of operating frequencies which we encounter in the typical cable distribution systems. As **the diagram here** shows, we might select a cable (.412 type which is just over 4/10ths of an inch in diameter; .412" to be precise) which has a measured loss of 0.68 dB per 100 feet **at TV channel 2,** and, 1.35 dB loss per 100 feet **at TV channel 13.** Ideally we would select a cable that has the **same loss** at channels 2 **and** 13 but this is not an ideal world; **there is no such cable.**

All cables utilized for cable TV systems have quite exact, and very predictable loss characteristics. If the manufacturer tells us the loss will be 0.68 dB per 100 feet at TV channel 2 (55.25 MHz), then we can compute that the loss in 1,000 feet will be 10 times 0.68 or 6.8 dB. Or for channel 13, 1.35 dB per 100 feet and therefore 13.5 dB for 1,000 feet.

We also have certain known criteria for each television receiver to be connected to our cable distribution system. Thirty-five years of cable technology and more than a decade of direct FCC involvement in cable's technical affairs has taught us that 'typical' television receivers respond

in certain ways to certain types of input signals. From this information and knowledge we know that we must design our cable systems so that they will deliver a certain grade or level of television signal on each cable channel to each television set connected to the cable. A representative set of FCC approved numbers appear here:

1) Signal level to subscriber receiver/**0 to + 10 dBmV**

2) Signal to Noise Ratio/**43 dB** (minimum)

3) Signal to composite triple beat/**51 dB** (minimum)

4) Signal to hum modulation/**40 dB** (minimum)

5) System response/ +/-1.5 dB within a 6 MHz wide channel, maximum.

6) Signal to beat interference/**60 dB** (minimum)

7) Signal to reflections (mismatch)/**40 dB**

Items 1,3,6 and 7 are set virtually totally within the cable distribution portion of the plant; items 2,4 and 5 are established at the headend but ultimately they can be degraded (but never improved) in the cable plant. An SMATV system, presently, **does not have an FCC requirement to meet any of these standards**. However, good engineering suggests that what are 'minimum performance standards' for CATV should also be minimum performance standards for SMATV. And, if you believe that one

day, before it is all over, SMATV will, like CATV, have technical requirements mandated by federal or other authorities, it is only good business sense to insure that your new SMATV system-builds at least attain the minimum CATV mandated standards.

In an earlier chapter we found that while the headend signal level may indeed be quite strong (such as +50 to +60 dBmV), the customer's television receiver(s) will not perform properly at such a signal level. Just as **too weak** a signal causes snow (noise interference) with any form of television reception, so too will **too much** signal cause interference of a different sort. That's why the FCC rules require that the cable operator 'adjust' the signal level to each subscriber's receiver to be within the region of **0 dBmV** (which is actually the same as 1 millivolt or 1,000 microvolts across or on a 75 ohm cable), and, **+10 dBmV** (3,200 microvolts or 3.2 millivolts on a 75 ohm line).

Yet we may have an SMATV headend which starts off with much higher signal levels: such as +60 dBmV. We previously learned that by using appropriate 'tap off' units we could 'isolate' the individual receiver outlets from the main (trunk) line signal, and extract just the required amount of signal voltage out of the main (trunk) line to deliver the appropriate signal level to the TV receiver. If we had a TV set located directly at the SMATV

headend, for example, and we wished to supply it with +10 dBmV, while our headend level was +60 dBmV, we would need to somehow 'isolate' our TV set from the headend by a 50 dB (60-10) device.

Recall, however, that our cable connecting our headend to our subscriber home **has loss** and that this loss is a function of frequency; at the end of 1,000 feet of our example .412 cable we had lost (due to cable resistance) 6.8 dB of channel 2 signal and 13.5 dB of channel 13 signal. Obviously we could not connect a signal tap or isolator device to the cable at the end of a 1,000 foot run and maintain **equal signals** on channels 2 **and** 13 to a TV set at that point; simply because channel 2 is 6.7 dB stronger than channel 13 (13.5 dB loss in 1,000 feet at channel 13 minus [-] 6.8 dB loss in 1,000 feet at channel 2 = 6.7 dB difference in level between the two signals). Obviously this 'relationship' between the lowest channel on the system (i.e. the one with the least amount of cable loss) and the highest channel on the system (the one with the greatest amount of cable loss) is only going to get worse as we get further and further and further from the 'power source'; our headend. The more cable we travel through, the more divergent the two extreme channels become in level.

And that brings us to the second most difficult design problem with an SMATV/CATV system; how to keep the signal levels close together so the

TV receivers connected to the line don't find channel 2 high quality, and channel 13 low quality (noisy).

AMPLIFIER Spacing

Very few SMATV/CATV systems can be totally served from a headend. That is, it usually takes more cable to 'wire a project' than you can run just out of the headend alone and still reach every home with a proper signal level. This means, as we discussed in our last part, that you must re-amplify the cable signal one or more times beyond the headend to compensate for cable attenuation (losses). Remember, the home wants to see between 0 dBmV and +10 dBmV level signals; anything weaker than 0 dBmV flirts with 'noise' in the picture and anything stronger than +10 dBmV encourages 'signal overload' problems with the TV receiver.

We can easily weaken the signal going to the home simply by placing an attenuator (fixed pad) in the line to the house; or, by using a tap-off device that 'isolates' that home TV set from the balance of the line by a prescribed amount of isolation (such as 50 dB or 10 dB). But what happens when you need the opposite type of cure; **more signal,** not less signal?

The answer is an amplifier; you select an appropriate signal amplifier and you re-amplify the signal that has traveled out of the headend through the coaxial cable to this point where the combined cable

losses have gotten severe enough that **any further cable losses** would make the signal(s) noisy and unuseable.

Remember that our cable has unequal losses at different frequencies (channels). Our high channels will weaken more, faster, than our lower channels.

We are familiar with noise in TVRO; when our signals are not sufficiently strong to paint clean pictures on our TV screens, we say there are 'sparklies present'. TVRO pictures are not supposed to have sparklies in them. We are also sort-of-familiar with something called carrier to noise and signal to noise ratio; we may remember that we need certain minimum ratios between the good guy (the signal) and the bad guy (the noise) or the bad guy (the noise) will infiltrate the good guy (the signal).

You may remember that a TVRO receiver is supposed to be 'good' if it has a 'carrier to noise **threshold'** or CNR of 8 dB. If you are more astute, you are aware that it takes a CNR in the 10 dB region to insure that our video picture not only has no sparklies, but it also has no 'busy background' (**non-sparklie noise**) present either.

Regular TV signals have similar measurement procedures. Only, because these are AM (amplitude modulated) signals rather than FM (frequency modulated), the numbers get bigger for the same effects. The FCC told us

that the minimum signal to noise ratio they will accept, inside of the subscriber's home, is 43 dB. You can relate to what 43 dB signal noise is on an AM signal by thinking about how an FM signal looks when you have a CNR of 8 dB. The two are about equal. An 8 dB CNR, is as we all know, a picture with just a hint of sparklies in it **if** we are dealing with a top grade TVRO receiver. Now it happens that if we are creating our SMATV pictures from a TVRO signal, and we have an 8 dB CNR at the satellite receiver, the video that comes out of the satellite receiver can never be any better than a 43 dB signal to noise ratio equivalent in an AM signal. So an SMATV system that starts off with an 8 dB CNR signal is going to be very borderline, according to FCC specs, to begin with. **We'll return to that** in a later segment.

To maintain a 43 dB signal noise ratio (SNR), we have to take special pains to insure that the cable signal never gets too weak (i.e. it never starts to get 'noise' in it) on the cable, before we re-amplify it again. This could (and would) happen if we allowed the signal to go too far in the cable before we ran it through a cable station amplifier. This, then, establishes a minimum cable line signal which we can tolerate before we must stick an amplifier station in the line.

Most CATV line amplifiers have certain 'minimum input levels' which

must be respected, by the system designer (he's the one who decided when and where and what to stick in the line for re-amplification purposes). A typical specification calls for an amplifier whenever the weakest channel on the line drops to +85 dBmV. Most systems function so that the actual minimum line signal before a re-amplifier station is added is actually higher than this number; **+12 dBmV is more typical,** and we will see why.

And that gets us back to the different levels between the highest channels (which have the lowest signal levels because of higher or greater cable attenuation), and, the lowest channels (which have the highest signal levels because of lower or less cable attenuation). Somehow these levels must be 'equalized'.

The simplest form of equalization is to start off the signals, at the headend, so that the lowest channel (channel 2 in our example) leaves the headend with a lower signal than the highest channel (13 in our example). If we approach it this way, here is what happens:

1) We know what the maximum output from our channel 13 headend modulator or off-air amplifier can be. For right now let's call it **+52 dBmV.**

2) We also know what the minimum recommended **input** signal level

can be, on that channel (13), to our first line amplifier station; let's call it **+12 dBmV** for now.

3) Now, we also know that the cable has **1.35 dB** of loss per 100 feet at channel 13.

4) Where does the first amplifier station have to go?

A) Headend output level-channel 13 = +52.5 dBmV

B) Minimum input level to first amplifier-channel 13 = 12 dBmV

C) Amount of cable loss practical between headend output point and input to first amplifier = 52.5 dB - 12 dB or **40.5 dB** of cable loss;

D) 40.5 dB of cable loss divided by 1.35 dB per 100 feet = 3,000 feet of (.412 type; example) cable.

Now we know how far 'down the line' our first cable amplifier should be (3,000 feet). Now, how do we calculate the permissible output level for our **lowest** channel; 2?

1) We know the length of cable (3,000 feet);

2) We know the cable loss at channel 2 (**0.65 dB** per 100 feet);

3) How much loss will 3,000 feet of cable have at channel 2 (**answer**: 30 multiplied by 0.65 dB (loss is .65 dB per 100 feet and we have 30 increments of 100 feet in 3,000 feet) = **19.5 dB**.

4) Then, at what level should channel 2 leave our headend?

A) If channel 13 will have 40.5 dB of loss, and

B) Channel 2 will have 19.5 dB of loss,

C) Then the difference between the two is 40.5-19.5 or 21 dB, and therefore,

D) The channel 2 output level at the headend should be the channel 13 output level (52.5 dB) **minus** 21 dB, or **31.3 dBmV**.

Now we have operating parameters for our headend, and we can see that in our example, we have quite a level difference between the lowest channel and the highest channel. This difference is often referred to as 'tilt' or 'slope'. The channels in between 2 and 13 will stair-step; channel 3 will be slightly higher than channel 2, channel 12 will be slightly lower than channel 13, and so on. In the end, we have all of the channels arriving at the input to our first line (re) amplifier at the same signal level; +12 dBmV. That's **one way** to make it work.

But the signal to noise ratio, translated to the minimum required input signal level to the line amplifier, is **only one** of the **many technical specs** that concern a cable system plant designer. Let's see what some of the others are:

1) The gain of the amplifier is not fixed, it is a variable function.

The amplifier has a 'gain control' and a gain control range.

2) In addition to the tunable gain-control-range, there is also a provision to 'pad down' (as in attenuate) the input signal when the amplifier station may be spaced closer to the signal source than 'ideal'.

3) The operating gain of the amplifier is a function of the number of channels (i.e. carrier signals) being transported on the cable. When you have **more channels** through the amplifier, you have **less gain available per channel**. The **total gain** is the same in all cases, but that gain must be **divided amongst** the number of carrier signals present.

4) Failure to 'derate' (as in tuning down) the overall gain of an amplifier, when you have many signals present, will cause one or two undesirable by-products:

A) The amplifier may exhibit something called **'cross-modulation'** (where the modulation from one channel/carrier superimposes itself on top of another channel on the system), or,

B) The amplifier may exhibit something called **'composite triple beat'** (where the various channels going through the amplifier

'beat or mix' together causing a new, second set of signals in the amplifier; interference signals coming from the mixing of the unwanted signals).

All of these considerations must be taken into design consideration when every amplifier in the system is selected (by model and characteristics), and placed in the plant at a specific point in the cable.

There are known parameters for derating (turning down) the gain of the amplifier, to compensate for potential cross-mod and 'composite triple beat' problems. You obey those rules for each amplifier station, or pay the price with degraded pictures. There are also known 'losses' associated with getting from the amplifier station in question to the next amplifier station; losses in the cable, losses in two or multiway line splitters, and losses associated with inserting customer tapoff (isolated connections) units in the line. Fortunately, there are relatively simple formulae to apply when laying out a cable distribution plant and we'll touch on those before finishing with this subject.

WHEN It Isn't

A quick glance at a line amplifier specification sheet might tell you that the amplifier is capable of 40 dB of gain and it is capable of operating at +52 dBmV output level. **Read further.**

The same sheet may also tell you that the amplifier is capable of 40 dB of gain and +52 dBmV output level **only for 7 channels**. And you have plans to carry 12 or 20 channels. We already know that more channels will cause us to derate or backoff the amplifier's output specification which is the same as backing off on the gain we can use.

Let's look at an example, here. The data sheet says that we can get +59 dBmV output with seven channels, +57 dBmV output with 12 channels, +54.5 dBmV with 21 channels or +52.5 dBmV with 30 channels. It also says that this would be for a **stand alone amplifier** where we were willing to accept a cross-mod number of -46 dB.

The -46 dB cross-mod number tells us that we **are** going to have cross-mod with this amplifier. It also tells us that the cross-mod will be 46 dB weaker (written as **-46** dB) than our output level. Another way of looking at this is that if our output level for 12 channels is **+57** dBmV, our cross-mod output will be 57 - 46 or **+11** dBmV. Is that adequate? Perhaps, but marginal.

The same amplifier data sheet also tells us that we must derate that amplifier by approximately 3 dB if we want the cross-mod to be down to -57 dBmV. A little study would reveal that cable systems maintain a cross-mod goal of -57 dB and that suggests that the -46 dB number may

not be that good. **It isn't.**

So we see now that the same amplifier, derated or gain-turned-down to a point where the **undesirable** cross-mod signals are at least 57 dB reference our output signal levels will have 7 channels at +56 dBmV, or 12 channels at +54 dBmV or 21 channels at +51 dBmV or 30 channels at +49 dBmV. This tells us that if we elect this particular line of amplifier, we would do well to operate in the 'CATV mode' which for 12 channels would be an output level of +54 dBmV.

Careful reading of the same illustration will reveal an asterisk. It says "3 dB block tilt" and "5 dB block tilt". What is that all about?

We used the term 'tilt' once before; interchangeably with the word 'slope'. The two are related, but in fact seldom inter-changeable.

Tilting

We already know that the cable losses are always going to be higher for the higher frequency/channel signals. And since our cable plant is made up of lots of cable loss, we will through the sum of the total cable plant have far more cable loss on channel 13 than we will at channel 2.

We have also figured out that between each signal source (headend or amplifier station) and the next signal amplifier, we are constantly fighting this 'uneven loss'. Everytime we leave an amplifier staion, we

have to be concerned that we will arrive at the next amplifier station without a tremendous (or troublesome) difference between the lower channels and the higher channels.

Tilt is one way to build in some of that difference, **from the beginning**. We saw how we did this when we left the headend, in our example; we 'tilted the output' on channel 2 so that it was +31.5 dBmV and the output on channel 13 was +52 dBmV; **a 21 dB 'difference'**.

Now it happens that we will almost always have a longer cable run between the headend and the **first** amplifier station than we will in any other portion of the cable plant. A 3,000 foot run in this example is about three times as far as a normal **amplifier to amplifier** spacing. It works out that when you have amplifier ouput levels and plant losses in things other than cable (such as splitters, taps et al), you end up moving amplifiers closer together. If the cable run from the headend to the first amplifier can be 3,000 feet in our example, but the typical cable run is 1/3rd of that, this tells us that we will be around **1,000 feet** between the first amplifier **and** the second amplifier, 1,000 feet again in between the second amplifier and the third amplifier, and so on. This also means that the difference in cable losses between channels 13 and 2 will be about 1/3rd of our headend to first amplifier example; rather than 21 dB

difference we will measure or find a 21 divided by 3, or 7 dB difference.

This is a far more manageable number than 21 dB.

So let's 'experiment' a little. Let's use a special control built into the amplifier to on-purpose 'tilt' the output of the line amplifier. We did the same thing back at the headend by individually adjusting the output levels on the individual modulators to obtain the appropriate tilt/slope we wanted for our example (+31.5 dBmV on channel 2, a little more on channel 3; up to +52.5 dBmV on channel 13, a little less on channel 12, etc.). We don't have **individual channel** controls in our **line amplifier,** but we do have a control that will attenuate the **lower channels more** than the higher channels. It is called 'slope' and it **'slopes the gain'** of the amplifier so that the output is higher on the high frequency end than it is on the low frequency end. **In our example,** we have an amplifier that is designed to operate all the way up to 300 MHz (well up into super-band, above channel 13) and it can slope '8 dB between 300 MHz on the high end and channel 2 on the low end'. We'll ask it to **slope 6 dB** between channel 2 and 13, but we'll help it by coming to the amplifier with slightly uneven signal levels; +12 dBmV on channel 2 and +15 dBmV on channel 13. **The combination** of the slightly tilted input (3 dB lower on 2 than 13) and the slope control built into the amplifier will give us the total of 6 dB of

output slope (or tilt into the next piece of cable).

Once this relationship has been established in the plant amplifier portion of the system it becomes a repetitive process to keep it going through the balance of the plant itself.

REMEMBER

Individual plant amplifiers have gain ability that is dictated by the number of channels through the amplifier (more channels, less gain available), gain that is limited by the level of permissible cross-mod in the system (-57 dB cross mod level is recommended for CATV plant quality pictures), and gain that is limited by the permissible levels of composite triple beat (interference). **All of these factors inter-play** with the plant layout, and the placement of amplifiers.

We'll see how you go about assessing a plant layout in the next chapter.

SMATV

Part 7

PLANTS

PURE TRUNK 'vs' Tapped Trunk

Cable television systems are designed with one goal in mind; to earn money for their owners. There are limited exceptions to this 'rule'; i.e. cable systems that have municipal (city) ownership or shared expense systems where all users jointly participate in the system's funding and operating costs. To make money with cable, you deliberately set out to do two things;

1) Attract as many people as possible to 'the cable' by providing on-cable **service which is better than** (quality of pictures) or more-than (more boutniful than) ordinary, over-the-air terrestrial television reception; and,

2) Spend **as little money** as possible achieving the first goal!

Cutting corners in cable system construction is an art; knowing where you can trim back in system design specifications without adversely affecting the system performance is no game for novices. Often what

seems like a good way to save $1,000 per mile of cable plant turns out to be a very bad operational mistake months or years after.

SMATV or private cable plants are no different; **or are they?** We have written that an SMATV system is really a cable system operating on different legal turf; private property versus public property. We have also written that a private cable system must seek to provide sufficient cable-only services to be an attractive 'alternate choice' for residents to whom the service is offered. In view of recent court decisions which seem to open up SMATV 'turf' to conventional cable (i.e. no exclusive areas for SMATV), and in view of legislation drafted to strengthen cable's role when faced with SMATV competition, it suddenly looks as if the cable operator may have an upper hand in competing with SMATV one on one in condo, high rise and other developments where SMATV once had an upper hand.

Here the discussion of SMATV plant (system) design focuses on an area where SMATV may still have a technical edge, albeit a rather shakey edge at that. Our focus here is on that portion of the cable plant called 'the trunk'.

The cable system starts at the system 'headend'. The headend

is where, as previous portions of this series have detailed, all of the cable-carried signals 'originate' for cable carriage. The actual on-cable services may consist of off-air VHF and UHF signals (so called 'terrestrial signals) plus off-satellite 'distant signals' (such as WPIX, WOR, et al), off-satellite specialty channels (such as CNN, ESPN, USA, et al) and off-satellite premium services (such as The Movie Channel, SelecTV, et al). All of these signal sources are individually treated and processed at the CATV headend and then 'bundled together' electronically in a single cable which will distribute them to the community or region where the cable system will operate. Once bundled, the first cable leading away from the headend facility is called 'the trunk'.

Trunk is a telephone terminology, perhaps stretched a tad. In the cable world, a trunk cable is a very special breed of cable where everything possible is done to maintain the very highest quality of the signals carried. There are several rules regarding trunks; 'rules' created by CATV system design engineers as 'minimum standards'. Every effort is made not to break those rules for to do so is to compromise the quality of the cable service channels carried by 'the trunk'.

1) No subscriber is **ever connected** to the cable by plugging into the

trunk.

2) The system signal to noise and signal to interference 'ratios; (the measurement of the good guys...the cable channel signals...to the bad guys...any type of electrical energy which might degrade the 'quality' of the good guys...) are maintained as high as technically possible on the trunk.

The first rule is easy to understand; you don't install a subscriber tap-off device (such as a 'directional tap') into a trunk line cable. We'll explore how you do connect up a subscriber shortly.

The second rule requires more ground rules.

All cable has loss, as we have studied. When the cumulative loss of a piece of cable equals some pre-calculated amount we must re-amplify the cable signal(s) with an amplifier. Every amplifier, no matter how good it is nor how much it costs, adds noise and interference to the cable signals carried.

This creates two sub-rules:

3) To maintain the highest possible signal to noise and signal to interference 'ratios' we want to use the cable which has the lowest possible 'loss', because...

4) To reduce noise and interference we want the signals to be re-amplified **as few times as possible** between the headend and the cable home.

This simply means that if we use large cable (larger diameter cable has lower loss) we can go further, inside of the cable between amplifier stations. Therefore, the trunk line usually will use a cable with a larger diameter than we will use in say the 'feeder lines'. Feeder lines?

What are they?

In an earlier part we explained that all CATV plants have two different levels of actual cable; the trunk line is considered the primary artery in the system, like a freeway built on elevated platforms across a city. No stop lights, no cross streets; you get on the freeway and travel at a high rate of speed until you arrive at the 'exit' you wish to reach your destination. **The exits are the feeder cable.**

Feeder lines literally 'feed signal/channels' away from the trunk line main artery into individual residential and commercial districts. **The subscribers are connected to the feeder lines,** using the directional tap-off devices which insert into the feeder lines of the system.

Feeder lines typically do not travel very far, in distance or cable

footage, away from the main trunk line. This is a system design consideration based upon the fact that the economics of cable requires that you degrade the 'quality' of your feeder line amplifiers significantly from the trunk line amplifiers. **You might** be able to operate **as many as** 128 or even more trunk line amplifiers in a line (i.e. cascade; one amplifier, cable, a second amplifier, more cable, all the way to some magic point where the noise and interference generated within each amplifier finally 'swallows' the pictures on the cable). But for feeder line amplifiers (called 'line extenders') you will more often operate three or perhaps six in a line; at which point the lower system specifications of the feeder line amplifiers will also cause the pictures to be buried in noise and interference.

So a **feeder** line is a **distribution** line; it distributes or carries the actual cable service to the individual subscriber yards. The line passes by each yard and from that point it is carried into the home, subscriber by subscriber, in even less fancy cable such as RG-59/U; the common stuff we use in the TVRO world.

This is not about feeder lines. This is about the trunk portion of the plant, and the possible derivations played by the trunk when you are

dealing with an SMATV or private cable situation.

HOW SMATV Differs from CATV

The CATV system headend may be almost identical to the SMATV headend; they might elect to use the same type of off-air receiving antennas, the same type of off-satellite antennas and electroncis. They might even elect to use the same type of modulators and other headend equipment. If that were the case, then the signals leaving the headend in the trunk cable from each would, in theory, be identical.

The CATV system designer will know in advance just how far he must 'stretch' his cable service, using his trunk line as his main artery, **to reach the far edges of his franchised area**. The SMATV operator will also know how far he must stretch his cable plant to reach the edges of his contracted property. Here is the major difference:

1) The cable operator will probably have to travel **miles** (tens of miles) in cable to take service to the edges of his service district;

2) The SMATV operator may have to travel **thousands of feet,** or perhaps a mile or two at most, to his 'most distance service point'.

The difference between 'thousands of feet/a mile or two' and 'tens of miles' is very significant. The SMATV operator will never need to be

converned about reaching the end of his territory before he has generated so much noise and interference in amplifiers that he will be degrading the service channels with 'system-made' interference. And that gives the SMATV operator a 'design option' which the CATV operator does not have. It is all about saving bucks.

Let's see how this works in diagram form.

We have a headend and because we come from the CATV shcool, we have designed it so that it has +30 dBmV output on channel 2 and +44 dBmV output on channel 13 (the uneven outputs are a function of cable 'tilt'; a subject previously covered). Now, if we elect to use a popular brand and model of 1/2" trunk cable, we find that we can send that signal through 2,636 feet of cable before the cable's attenuation has decreased our in-cable service level to +15 dBmV. The +15 dBmV is an important number because we have learned that a quality trunk amplifier must have a specified input when we re-amplify it.

But suppose that our trunk is not simply a 'straight shot' through cable to the next amplifier station; it is a trunk system which must be 'split up' along the way to create sub-(trunk)-arteries to send signal down other streets or alleyways in the community. In other words, the trunk has to

split because the people live in several directions (not just one) from the headend. The 'splitting' of the trunk signal causes us to lose some of the signal. In the real world, each time we split the signal (divide in two) we lose around 3.5 (to 4.0) dB of trunk signal 'strength'. Another way to look at that 'trunk loss' is to ask ourselves 'how much 1/2" cable is the equivalent of losing 3.5 (4.0) dB? **There is a numerical answer**.

So in the bottom of our diagram we see that if we add a trunk line splitter someplace between the cable heaadend and the first amplifier station, we have just effectively shortened the distance from the headend to the first (required) amplifier (station). The cable length is now 2,272' rather than 2,636'. In effect, we lost more than 350 feet of 'cable' ability in the process of inserting a splitter in the trunk line.

To further illustrate what happens, below the splitter inserted in the main-artery (top line) run, we also have taken the **first** two-way split and we have **split it again**. This is not uncommon in the CATV world. Now we have not one but two 'bulk signal losses' in the trunk line. In the top trunk run we dropped from 2,636 to 2,272 feet of cable **prior to** our first amplifier. In our bottom example, the second splitter got us down to 1,905 feet (all distances are measured from the headend output fitting to

the input fitting on the trunk line amplifier).

There is one more point to notice.

In our top example, we had arrived at the 2,636 foot point with both channel 2 and channel 13 **'equal'**; both had attenuated to a signal level of **+15 dBmV** due to the fact that the cable has higher (greater) losses at channel 13 than at channel 2. Now however the cable is shorter than in our original example so we can reasonably expect the difference between the channel 2 and 13 signals to also be something other than 'even'.

If we left our headend operating with +44 dBmV output level on channel 13 and +30 dBmV output level on channel 2, as in our original example, we would now find that in all three indicated trunk amplifier locations (1, 2A and 2B) we have **more signal on channel 2** than we have on channel 13. The reason, just stated, is obvious; it took 2,636 feet of cable for the higher loss channel 13 to balance to the lower loss of channel 2; resulting in both channels reaching the amplifier even though they started out in the headend with channel 13 **14 dB higher**. If we shorten the cable, but leave the headend output levels still at 2/+30 and 13/+44, we can expect channel 2 to now be stronger at the input of the respective amplifiers (1, 2A and 2B). It is, by as much as 1.3 dB.

The answer is to turn up the channel 2 level (or turn down the channel 13 level) at the headend; we'll explore that further, shortly.

Now let's look at our first example of how we save money in SMATV. And get the jump on a local cable system operator.

NON-PURE Trunk

Remember that we don't mess-with-the-**trunk** because we know, in CATV, that the trunk is our 'main artery' of lifeline carrying signals to the furthest extreme of the community. But if our furthest extremes are **quite close,** why must we adopt a CATV-like-system of main arteries and sub-arteries or freeways and exits, at all?

Each generalized plant design choice will depend upon the size and scope of the facility or region to be covered. There is no hard and fast rule that tells you thaty ou 'must' use CATV wiring specifications whe nthe plant is larger than XX miles but you can use SMATV type techniques when the plant is smaller than Y miles. It is not that simple; quite.

There is a technique here called 'tapped trunk' and we have a diagram to illustrate the principle. It recalls that the pure trunk was able to send the bundled headend signals through 2,636 feet of 1/2 inch trunk

cable before we reached the first amplifier station. That's a review; the bottom of the diagram is the 'new stuff'.

Suppose we start to service customers right out of the headend (say within 100 feet) and we decided to (horrors of horrors!) **tap the trunk**. In other words, we violate the first rule of good CATRV plant design and we insert a cable tap-off device (directional coupler) into the 1/2 inch trunk cable. What really happens here?

If our total plant length is short; if we know, for example, that we can reach the outer limits of our cable property within say 2,500 feet of cable from the SMATV headend, why not simply run a single 'cable' and avoid the added expense of running a trunk plus feeder lines? Certainly anytime you are installing two cables (one as trunk and one as a feeder) along the same stretch of roadway or easement, you are spending more money that if you were installing but a single cable. Can you make one cable serve you twice; as a trunk AND as a feeder? The answer is yes, if you are careful!

The level problem first. In the bottom of our new diagram we have inserted directional taps at 100 foot intervals starting 100 feet from the SMATV/headend. The taps are a popular GI/Jerrold tap-opff, CATV grade quality, and each of the tap-off devices has four separate output spigots.

That means that you could connect-up **four** homes or four apartments or four condos **at each location** where we have shown a 'tap'. What happens when we do this?

In out trunk-only system we have no loss along the cable **but the loss of the cable** itself. We understand 'that loss' since all cable has attenuation. In our 'tapped trunk' we have this cable loss PLUS we also have loss caused by the directional tap services. Therefore we have a 'sum loss' made up of two components. We can calculate the loss in the cable proper at both channels 2 (our lowest channel) and 13 (our highest and therefore most 'lossy' channel) and **to that loss** we must **add** the loss of the directional tap. Think of the tap in this way:

> **The cable channels on the trunk have a measurable 'voltage' or 'pressure' each. The directional tap is like a very small piece of tubing inserted into a watering system. A small** (fractional) **amount of the signal 'pressure'** (voltage) **being carried on the trunk line siphons off of and out of the trunk into the 'small tubigg'** (the directional tap). **You can measure that difference in pressure** (signal voltage) **before** and **after the tap; it will be slightly** lowere **just** after **the**

tap than it was just ahead of **the tap because** some **of that pressure or signal voltage has flowed into the directional tap and to the homes connected to the directional tap.**

So now as we go 100 feet/200 feet/500 feet and so on down the 'tapped trunk' and away from the headend, we have both the loss of the cable (attenuation) **plus** the loss of the tap (siphoned-off 'pressure') adding up. This means that just as we had to shorten the trunk run from 2,636 feet to 2,272 feet when we inserted a two-way splitter in the line in our 'pure trunk', we now have to shorten the tapped trunk run to some even shorter distance to allow for the insertion of the directional taps.

There are several factors here at work, simultaneously;

1) The cable losses are higher at the higher frequencies (i.e. channel 13 losses are higher than channel 2 losses in a given length of cable);

2) The directional tap 'losses' are ALSO higher at the higher channels.

Therefore in a given length of tapped trunk, channel 13 will get 'weaker' considerably faster than channel 2. But, remember that we started out at the headend with channel 13 at a level that **was 14 dB stronger** than channel 2; so we could end our first-leg journey, at the input to the first real line amplifier, approximately 'equal' between 2 and

13. So what happens at those cable subscriber homes 'close to' the headend? Won't channel 2 be far weaker than channel 13?

Your attenuation is drawn to the fine print in the diagram. Note that we have T1, T2 and so on to T6. These are directional tap-offs units. Each one extracts some signal (pressure) from the (tapped) trunk line and diverts that signal (pressure) towards one of four subscriber locations. The numbers adjacent to each tap tells us what the channel 2 **and** channel 13 signal **levels** will be **after** each tap; the sum here of the cable loss and up to the tap, and **the tap loss within the tap**.

Then we have a length of RG-59/U 'drop cable' carrying the signal away from the tap into the home. We'll assume this is a typical American home and it has two TV sets and therefore two TV outlets connected to the cable. That means at the end of 100 feet of RG-59/U we have a **two-way splitter** needing signal to a **pair** of TV sets.

In between the tap (T1 etc.) and the in-home two-way splitter we have the 100 feet of RG-59/U and a number with a minus sign to the left; **i.e. -20.** That minus 20 tells us that the directional coupler installed in the tapped trunk **at that point** was designed to result in a signal siphoning through the tap that would be 20 dB lower in level (i.e. -20 dB) than the

actual signal on the trunk line at that point. This factor (-20) is a variable; you can select various tap 'values' to suit the location of your tap in the plant; a tap close to an amplifier, or the headend in our example, would siphon off less pressure than one further away from the amplifier to headend. Not less in terms of **signal**-to-the-TV-set, but less in terms of how much is available to be siphoned off.

Down at the bottom we have the actual signal level to the TV set, after the RG-59/U cable and the in-home two-way signal splitter (it also has 4 dB of loss). In our T1 example, the tap nearest the headend, we have a signal that is +3.46 dB 'strong' on channel 2 and a signal that is +15.2 dB 'strong' on channel 13. If you recall the discussion on FCC specifications for **cable** plants, the largest variable they allow between the weakest channel and the strongest channel, as delivered to the TV set in a home, for CATV systems, is 10 dB. Obviously we have a problem here. We'll come back to that problem.

Now switch your eyes to T6. That's at the end of our short plant diagram. It is the tap furthest from the SMATV headend. Now we see that the subscriber levels are +5.8 dB on channel 2 and +13.2 dB on channel 13. These are less than 10 dB 'apart' in level so this particular subscriber

'drop' would be FCC 'legal'.

This points up the first special design problem facing the SMATV system designer which only marginally affects the CATV system designer:

1) In CATV, we design our headend output level, and our trunk amplifier output levels so that we arrive at the **next** amplifier station with an input signal region which matches the recommended input levels of the trunk amplifier in use. This is only a modestly difficult situation because we are fighting only 'cable losses' in this design, and the cable losses are known.

2) In SMATV, when we begin to 'distort' the trunk by inserting directional taps in the trunk line, now we have a **'new source' of signal loss** and it is also 'frequency sensitive' (i.e. the losses are greater at the higher channels than at the lower channels). **Plus,** now we must be concerned about the level reaching the next amplifier **PLUS** the level reaching every single subscriber along the way, starting with the first tap that may immediately follow the headend or amplifier and continuing on through to the last tap just ahead of either the end of the line or the input to the NEXT amplifier station.

That's a lot of balls to have in the air all at one time. But it can be done if you are sworn to save yourself a grand or more per cable plant mile.

Let's see just how severe the problem might be with one more diagram. And, how if left alone long enough it **begins** to rectify or correct itself. We have a table/graph here that shows only one element of the system; using our original headend output level of +30 dBmV on channel 2 and +44 dBmV on channel 13, **we measure the channel 2 and 13 signal levels** at the end of each subscriber's 'drop line' after their internal two-way splitter. We see that the 'difference in signal level', on channel 13 (strongest) to channel 2 (weakest) varies from 11.74 dB at tap one (T1) to 7.4 dB at tap six (T6). That suggests a 'quick fix', **simply raise the channel 2 level by 7.4 dB** in this example and now we would have a maximum difference at T1 of 11.74 - 7.40 or, 4.03 dB while at the 'end of the line', T6, the difference would be '0 dB'. Let's see what that does to our other element; the input level to the first trunk amplifier. Remember, this is only the first 'chunk' of our CATV plant; there are more amplifiers and more 'chunks' ahead and we have to somehow keep all of these balls in the air **clear to the end of the system!**

In our **next diagram,** we take the major part of our just-given advice and we modify the output level to +36 dBmV/2 and +44 dBmV/13. Recall that when you set up a headend, you 'balance' the levels using the individual carrier level controls on the modulators to suit your system design needs. Raising the channel 2 (3 etc.) levels a few dB is simply a matter of:

1) Determining how much 'up' to go, and,

2) Connecting a signal level meter to an appropriate test point and turning the controls 'that amount'.

In our new diagram we have bunched the first four taps into a single diagrammed tap (they are stand alone in the real world) and have begun our detailed analysis **at the T5 location,** some 500 feet down-line from the headend. With +36/2 and +44/13 out of the headend, we now find that the T5 subscriber signal levels are +12.44 and 14.66 for channels 2 and 13. The tap in use here is -12 dB (isolation) and we could have gone to a higher isolation number (such as -17 dB) and dropped both of these numbers by roughly 5 dB. Switch your eyes now to the end of the line; the T9 (A) tap.

Here we have three choices. T9 (a) is a 10 dB isolation directional tap which would deliver +0.34 signal on channel 2 and -0.30 signal on

channel 13 to a subscriber connection at the end of 100 feet of RG-59/U and past a two-way splitter for the subscriber. The -10 dB isolation tap is about as low as you can normally go, and still go 'on' to another segment of cable. The +/- 0.0 dB signal levels for channels 2 and 13 are marginal; very close to the 0 dBmV 'minimum' cable requires.

Let's assume this IS the END of the line; **there are no more subscribers** and therefore no more cable beyond this point. This gives us another option. If we don't have to carry the trunk line further, we can simply install a terminating tap; one that 'terminates' or 'caps off' the trunk line at this point. If we elect (and are able) to do this, we can now drop to an isolation value of -6.8 dB (again, using a standard catalog GI/Jerrold tap-off device) and now rather than being plus/minus a few tenths of a dB from 0 dBmV we are in the plus region at the subscriber's set; +3.54/2 and +2.90/13 to be exact. That's a second choice (T9B).

The other possibility is that we have a new amplifier to feed signal to this location. Let's see how that works, since it begins our sequence of taps and signal losses all over again!

In our last diagram for this segment, we go back and locate that if we were using the T9A selection (last tap in line being a -10 dB

isolation tap), we had a signal level AFTER the T9A tap of +13.42 dB/2 and +14 dB/13. Those are numbers which are very close to the original suggested +15/+15 levels for channels 2 and 13 as **input levels** to a trunk amplifier (remember the simplistic cable-only loss with 2,636 feet of cable)?

That means we can go now into a new trunk line amplifier with the .02213.24/2 and +14/13 input signal level and re-amplify the trunk line signal **before** we begin our **next series** of taps on the tapped trunk. This is shown with a nominal trunk line amplifier gain of just over 17 dB on channel 2 and 22 dB on channel 13. The result, diagrammed, is +32/2 and +36/13 output signal levels. And now we are ready for the first directional tap **AFTER** the next trunk line amplifier.

Note that as we start this next sequence, we are doing two things:

1) We are at a level that is significantly lower than our headend, at the output (+32 versus +36 at channel 2; +36 versus +44 at channel 13). This is because we will usually be utilizing trunk line amplifiers with far lower output capabilities than we have built into the headend. There are exceptions to this rule, but we'll slide past them for now.

2) The difference between 2 and 13 is now 4 dB (+32 and +36) rather than 8 dB (+36 and +44). This is because we will not be able to travel through 'as much trunk cable' on our way to the **second** trunk amp as we traveled through on the way to the **first** trunk amp; with the overall trunk amp output level LOWER, we cannot go as far before we will require our THIRD trunk line amplifier. With less distance to go, the difference between the highest frequency channel (+36 dBmV) and the lowest frequency channel (+32 dBmV) will be less (shorter cable, less cable-tilt loss to compensate for).

Now notice where we are with the subscriber tap-off level, as delivered to the TV receiver(s) through the standard 100 feet of RG-59/U and the on-premises two-way splitter. It says we will have +8.46 dB/2 and +10.2 dB/13. Those are obviously pretty decent numbers.

AN OBVIOUS Point

We started this session by comparing what happens in a piece of 'pure trunk' cable when we connect it to a headend with +30/2 and +44/13 signal output levels. We found that after 2,636 feet of 1/2 inch cable we were at a cable level of +15/+15 on channels 2 and 13.

We then proceeded to install directional taps in the pure trunk and we

turned it into a 'tapped trunk'. Now we had the cable loss plus the directional tap loss to contend with and as we progressed through that design part we found that we were ready to re-amplify again (+13.24/+14.0) after **900 feet of cable** loss plus directional tap loss. And this was AFTER we re-adjusted our headend output level to 36/+44 to compensate for what was obviously too little low-end (channels 2,3 and so on) signal voltage level.

This tells us that the pure trunk is about **293% as efficient** as a tapped trunk; using the particular 1/2 inch cable we have selected; and placing four-way directional taps at 100 foot intervals through the trunk run.

So there is an obvious trade-off at play here; you can go further, **always,** in a 'pure trunk' but you **can serve people along the way** 'for a price' if your total plant length (greatest distance from the headend to the last subscriber location) is relatively short.

A few closing words about selecting amplifiers for this application. We earlier noted, reference feeder lines, that most 'line-extender' type amplifiers tend to be rated such that you can stick three (or perhaps six if you keep your output levels turned down) 'in a row'; called cascading of

amplifiers. Beyond 3 (or 6) you will have so much noise and interference contribution from the amplifiers that you will be 'wallowing' in both along with the signal; and customers cannot be expected to pay for cruddy pictures. You could design a plant up to say three amplifiers deep (i.e. the longest leg to the furthest subscriber would have no more than three amplifiers on it) **using line-extender grade amplifiers**; and probably come out OK with the tapped trunk approach. Such line-powered amplifiers, capable of handling 12/20/36 or whatever number of channels are in the $200/$300 price region, and even lower if you shop around for 'bargains'.

There is another approach; you elect to use the **higher grade** (lower noise and lower cross modulation/composite triple beat interference level) **trunk amplifiers** in your plant. Now you can go several dozen 'deep' if that is required, tapping the trunk all along the way, or shifting alternately from 'pure trunk' to 'tapped trunk' as you go. This costs **more per** amplifier (two or three times as much per amplifier 'station') but it gives you better service and greater 'cascade ability' in the process.

If you study the facts and design your own plant, you will come to your own logical conclusions. Many times you will 'layout' the plant a half

dozen times or more, on paper, before coming to the 'right solution'. Each time you change an amplifier type (and specifications) you will find yourself re-calculating the plant losses and gains and relocating equipment. This is all time well spent, although you can also go to an equipment supplier (Blonder-Tongue Labs, GI/Jerrold, Channel Master, Winegard) **and ask them to do it for you.** They may do it 'free' in exchange for your buying your plant equipment from them), or they may charge you a modest fee for the service. If you take your rough plant 'layout' to two or more such suppliers, you may well receive back several completely different approaches to laying out the exact same plant. There may be only one 'best way' or there may be several equally good ways to do the same job. If you handle the work yourself, after some study and lots of kitchen table layout practice, you will always be ahead of the game because then you will select equipment based upon just your own design objectives and not the 'sales objective' of a commercial system designer (yes, it is possible to get back a plant that calls for using far more equipment than you really need; **remember** a free layout is **in exchange for** using **THEIR equipment** and the more you use, the better THEY like it!).

SMATV

Part 8

INSIDE WIRING

SHARE It

We now find ourselves at a crossroads in system design and performance. The basic SMATV concept differs little from CATV (cable television), with the primary difference being the 'scaled down' approach to SMATV system design. There is, however, another aspect of 'shared systems' which has taken on additional importance during the past twelve months. It is neither SMATV nor CATV: **some** are calling it **'MicroCable'** for lack of a more explicit name.

This revolution within a revolution begain in the spring of 1981 when an engineer in South Dakota named **Keith Anderson** demonstrated a new approach to low-cost receiver design. Anderson had observed that many of the more expensive receivers then being developed used somthing called 'block downconversion'; a technique which downconverts or shifts the incoming microwave frequency band (3,700 to 4,200 MHz) to a new frequency band in the VHF or UHF region. Anderson did not pioneer that

concept (that was done by one Steve Richey in 1978); he did pioneer the **low cost** approach to block downconversion.

The basis for the BDC low cost approach has been **'shared terminal-use'**. That is, two or more receivers, connected to the same TVRO antenna (and LNA) producing independent transponder/channel selection at each receiver location. The multi-receivers might be located in a single home, or they could be located in multiple residences. That is a 'legal' question, not an engineering problem.

The method and practice required to make such an installation properly perform with antenna and LNA choice will be left for another time; our focus here is on the distribution portion of the system to point out what the installer must be conscious of, and how he grapples with the 'distribution of RF energy' design **limitations** in such a system.

BASIS

Any RF (radio frequency and that includes 'television frequency') can be 'split'; or, divided into parts. The principle is precisely the same as dividing a 'visible' commodity such as a quart of milk. One quart of milk can be divided equally into two pints, four cups, and so on. The total **sum** of signal 'voltage' present before the 'split' is found once again (minus

minor split losses) after the split, **only in two or more separate** 'containers'.

The most basic 'split' is simply a 'divide by two'; the signal is electrically split into two equal parts. If you remember your electronic theory, each time you **double** your signal voltage, you have **increased** the signal 'level' by something called 3 dB. Converseley, each time you **divide** the signal voltage, you have **'lost'** 3 dB or more appropriately, you have created two, new equal signal voltages **each of which** is 3 dB lower in level that the signal voltage you began with.

That suggests that a two-way splitter will produce two signal voltages that are 3 dB weaker at each 'output port' than the incoming, original, unsplit signal. This is not quite so perfect a world and **there are small signal losses** attached to the splitting process. No splitter ever built produces two signals that are precisely 3 dB lower in level than the original signal because of those losses. The real world number is more like 3.5 to 4.0 dB 'weaker', per output port, so when we are planning such a system, we take the 'safe route' and call it a 4 dB 'loss' on the output side of the (two-way) splitter.

A two-way splitter, such as this, is one of the primary in-home wiring

components for a CATV or SMATV system. A TVRO BDC system, however, has at least one special consideration which CATV or SMATV does not have; the individual receivers must be kept 'isolated' from one another. How's that?

When we hear the term 'isolation' in TVRO, we normally think of another breed of receivers; **single conversion**. Single conversion receivers have speical problems relating to their capability of interfering directly with one another when connected to a common antenna (or when operated with separate antennas in close proximity). Isolation, as it relates to BDC receivers, is another type of 'problem'.

In any BDC system, you have one 'master' receiver and some quantity of secondary or 'slave' receivers. The master receiver also serves as the 'powering source' for the LNA and downconverter. If the master receiver is capable of sending power to the LNA and downconverter through wires separate from the coaxial cable that carries the BDC TV signals to the receivers, there is no tuning or operating voltage on the coaxial cable that carries the signal, you can skip over this part. However, most such systems use the coaxial cable to send TV signals from the antenna to the indoor receivers, **and,** they use the **same** coaxial cable to send operating

voltages for the downconverter plus LNA outside to the antenna mounted equipment.

Which brings us back to the splitter, any splitter, that appears in the coaxial line. If the splitter is passing and splitting TV signals from outside to inside, it must also be capable of passing **voltage** from the master receiver to the outside electronics. Can a splitter handle this?

We'll return to that question. There are additional considerations for the splitter as well, shown here in **diagram** form.

1) Is the splitter designed for the correct frequency **range** of the BDC signals (not all splitters cover the spectrum of the BDC 'IF' signals and this is a very important consideration).

2) Is there some form of 'RF' **isolation** between the output ports, just to be sure that some problem in one receiver does not cause reception problems with other receivers on the same antenna?

3) Is the splitter designed to **'match'** the cable impedance and type being used in the distribution system (BDC systems in our industry commonly use 75 ohm cable and connectors; check for compatability before selecting splitters)?

4) Is the splitter designed to **protect itself** against an ingress of

moisture (if it will be mounted out of doors, as many are, has it been designed to keep moisture out)?

Frequency range first. Different engineers have approached the BDC design from different vantage points and there is a lack of uniformity bvetween BDC suppliers. Not everyone has agreed on the same 'IF' or intermediate frequency range for their products. What does that mean?

The BDC system shifts in frequency the incoming 3,700 and 4,200 MHz (or 3.7 to 4.2 Ghz) satellite signals; downward to a lower frequency. The designer is free to select what 'lower frequency range' he likes for his IF (intermediate frequency). Not all make the same choices. We show that here in graphic form, Note that we have firms such as AVCOM and S/A electing to use relatively low fequencies (270 - 770 MHz) for their BDC IFs; and at the opposite end we have Winegard selecting a quite high frequency (1,140 to 1,640 MHz) for their BDC IFs. As the graphic depiction shows, there are several 'combinations' in use scattered between 270 MHz as a low frequency and 1,640 MHz as a high frequency.

Obviously an AVCOM BDC that downconverts the TVRO signals to 270-770 is not going to work with a Winegard indoor receiver that tunes 1,140-1,640 MHz. But that is the least of your design 'problems'. The very

nature of the splitter (or 'passive') devices is that they have an operating frequency 'range'. Splitters are common of course; CATV systems use splitters which are designed to operate from around 5 MHz up to perhaps 450 MHz (although you must always check the specs on a CATV splitter since many have been designed to operate over a lower frequency range such as 5-220 or 5-300 MHz). MATV systems, especially those that carry UHF TV signals 'inband' (between channels 14 and 83, 'on-channel') may be using splitters rated from 470-890 MHz (or 5-890 MHz). Consumer splitters, those sold at Radio Shack (et al) typically are rated for VHF and UHF, which means they handle 5 (50) to 250 (VHF) andd 470-890 (UHF) **either in** two separate bands (with a 'hole' between 2550 and 470) **or** they handle the full region from 50 to 890 MHz.

When a splitter is used 'out of band', that is, on a frequency or frequency range for which it was **not designed** nor intended, you have reduced performance; rather than 4 dB 'loss' in a two-way split, you may find 14 or 24 dB 'loss' in the 'out of band' portion (or virtually any other undesirable number). Therefore, selecting a splitter which is capable of handling the frequency range presented by your BDC 'IF' is very important.

Note that if you selected splitters rated from 5(50) to 890 MHz, you

would be OK for the AVCOM/S-A/Microdyne BDC IFs in the 270-770 region. But what about the others; those that use 400-900, 430-930, 450-950, or 900 to 1400? How do you split those signals?

Carefully; very carefully!

The easy ones first; most of the firms offering 900-1400 (or 950-1450) MHz IFs are following in the footsteps first laid down by **DX**. And the folks at **DX** realized before they released their products that they would have to supply 'passive' and even 'line amplifiers' in their chosen IF range (originally 900-1400, more recently 950-1450) if they were going to sell their systems. Thus there is a line of **DX** passives (CP-6 power block, DS-772 two-way 'power divider') and DS-774 four-way 'power divider' or 'active passives' (US-3S) which make it possible for all of the equipment using the 900-1400 (950-1450) 'IF region' to survive in the marketplace. We'll look at how the choice of IF (i.e. 270-770 **or** 900-1400) affects the system planning subsequently. For now, be aware that a splitter designed for CATV, MATV or home use will not process signals in the higher IF bands.

Isolation. Here we are concerned more with interaction between the multiple receivers than interference (such as we might have with single

conversion receivers). And, we are also concerned with the way we supply operating power (voltage) to the LNA plus downconverter that services the multiple receivers. Remember that the master receiver will supply power to the LNA plus downconverter through the same cable bringing signal 'inside'. We can split the signal into multiple parts; but what happens to the **power** that is in that line?

We diagram it here for you **(powering by Cable Considerations)**. The RF signal coming indoors is split in two (**one** output port shown) going one way; what is to keep the power, coming into the splitter from the output side, from also going back out of the splitter towards the second receiver?

There are two problems here:

1) If **both** receivers are sending power to the downconverter/LNA, we'll have both sets of power (voltage) present in the splitter. That's bad news; one is enough, two is too many.

2) Even if we have managed to turn the LNA/downconverter power 'off' at the second receiver, the splitter is still apt to feed power/voltage back to the second receiver from the first receiver.

There are several answers to this; you have to adopt one of those

approaches to avoid powering problems.

1) If your two-way (or four-way, etc.) splitter is not designed for this specialized applicaton, you need to modify it externally with a device called a 'power block'. This is a $5 item at most MATV/SMATV supply houses and it has F connectors on both ends. It inserts 'in-line' at the output of the splitter, in effect 'blocking the power' from leaving the splitter at that port. The RF signals pass through OK, the powering voltage is stopped at the block. If you have three or four (etc) outputs, you install a power block at all output terminals **except** the one connected to the master receiver (the one that powers the LNA and downconverter).

If you adopt this approach, the system is now virtually 'fail safe'; no matter how a switch at the receiver gets thrown, you cannot accidentally get two (or more) power-voltage sources operatng to the LNA plus downconverter. This is the recommended installation technique.

2) You can elect to use splitters with built-in power blocks; the DX DS-772 and 774, for example, have one clearly marked 'power here' output connector and the rest are internally blocked, inside the splitter. This is also a virtually foolproof method.

3) You can very carefully insure that all secondary receivers have

their powering switches switched 'off' so no voltage can leak out of that receiver into the 'system' and other receivers.

The problem here is that the customer may accidentally discover and flip that switch one day putting the system out of service.

HOW Much Loss?

The first mistake installers make with planning a BDC distribution system is to overlook the different nature of 'system losses'. Not all losses are created equally!

Let's start with **'Signal Splitting Losses'**. We have a signal source; our downconverter. Traditionally it is installed out of doors at the antenna or feed. Connecting it to the receivers we have a run of cable which gets us inside or nearly inside.

Entering our example **(illustrated)** building, we have a two-way splitter to feed two separate lines. Up to this point we have two different losses to consider:

1) The **loss of the cable** from the downconverter to the first two-way splitter, and,

2) The **loss of** the two-way **splitter** itself.

Now we have two different pieces of cable which lead towards a

pair of sub-distribution systems. One (to the top of the diagram) goes to a second two-way splitter which in turn has additional coaxial cable to receivers **1A** and **1B**. The other goes through cable to a four-way splitter which contributes additional loss, followed by yet additional cable to the four receivers labeled **2A** and **2D**. All of these losses add up, as we shall see.

At this point we have not answered the key question; how do we compensate for these cable and splitter losses to insure that each receiver (1A-1B, 2A-2D) receives the recommended minimum input signal required for quality pictures?

We have several other questions we must first answer.

1) What is the **normalized output** of the BDC (in dBmV)? This will be a number such as +10 dBmV which indicates a certain amount of signal voltage leaving the BDC. We make the assumption that his number is relatively 'flat' or 'equal' across the full BDC band, or transponders 1 through 24. We'll return to that assumption subsequently.

2) How does that output number (+ dBmV cited as an example) **change** as a function of antenna system gain? For example, if the number

is +10 dBmV in an area such as Kansas with a 100 degree LNA and a 10 foot dish, what would that level be in Florida with the same dish and LNA? **Chances it will be lower**. Knowing this is important because of another unanswered question (minimum signal level required to each receiver, at the end of he 'distribution chain').

3) What is the recommended input level to each receiver? The number here will (from manufacturer data sheets) be something like 0 dBmV (the same, you may recall, as 1,000 microvolts). Knowing the recommended level will help us design a system to achieve that level. Not knowing the recommended level will be like going hunting with blinders on; we won't know what we are 'shooting at'.

4) And the worst case situation; what is the **minimum** (as opposed to the recommended) input level for the receivers to be used? Numbers in the -5 to -10 dBmV region are common, but remember that **minimum means** a **degraded picture** and less than full-quality reception for the users.

Reference one more time to 'Signal Splitting Losses/BDC' and notice

that in our example we have 20.25 dB of 'loss' in our top ("1") receiver distribution line, and 33 dB of loss in the (worst case) of our "2" receiver line. Those are pretty big numbers, but what do they tell us?

FIRST Cable Loss

In the 70 MHz 'IF' (single conversion) receiver world, cable loss characteristics are at most a minor annoyance. They are far more serious a concern when we are dealing with BDC receivers which span 'octaves' of frequency. Let's see why.

Cable loss, if there are no splitters in the line from outdoors to indoors, is a function of frequency; higher frequencies have more loss in shorter lengths of cable than lower frequencies. We'll inspect the 'frequency vs. loss' factor shortly.

When we are planning (or pre-checking) a system design, we make all of the 'worst case' assumptions first. That means we add up **the worst losses,** and those are the losses which occur at the highest frequency in use or being carried by the cable. If the BDC 'IF' is 270-770 MHz, our concern is with the '770 end' since that is where the cable (and therefore, system) losses will be the greatest. If the BDC 'IF' is 440-940, again, 940 is our number of concern.

All cable has loss; a diagram here has selected some of the more popular (Belden brand) cables available through normal jobbers for comparison. We want to know, from the diagram, how much of various types of cable we can 'string out' before we have 10 dB of loss at our highest frequency of interest; in our example, 940 MHz. Note that we have RG-6, RG-6A/U, RG-11 and RG-59 types of cables here. Those appearing in **bold face** are the **best choices** for both loss and cable strength and integrity.

Well, if we know what our cable loss per foot is (at the frequencies of interest), and we know how many splitters and what types of splitter we will be utilizing, are we now getting close to specifying some type of 'amplifier' to overcome those BDC distribution system losses? Close, but we have some more homework to do. In our **'Amplifier Selection'** diagram, we walk through the example system; 33 dB of loss on the longest receiver run and a minimum input to the 'most cable distant' receiver of 0 dBmV. We started out with a +10 dBmV from the downconverter, so we can now compute at least the **gain** requirement for the amplifier.

1) +10 dBmV (downconverter output) minus (-) 33 dB of system loss equals (=) minus 23 dB. Remember that 0 dBmV is not representing 'no signal'; in the dBmV world it represents the 'recommended input' to a receiver; anything **greater than** 0 dBmV (or 1,000 microvolts on a 75 ohm coaxial cable line) is represented by 'plus' (+) signs and anything **lower than** this is represented by a 'minus' (-) sign. This is handy because when we see -4 dBmV written out, or on a meter scale, we instantly know we are 4 dB lower than the recommended input level.

Our 'Amplifier Selection' diagram shows us that if we insert a 23 dB gain (or 23 dBg) amplifier after that signal source (downconverter) we will now have a +33 dBmV output. That means that as we wind through the example system, we will end up at the receiver 2D location (our most distant receiver) after 33 dB of system loss with 0 dBmV. Is that all there is to selecting an amplifier; knowing how much gain we need to overcome the losses?

AMPLIFIER Selection Parameters.

Not quite. We need to know that our amplifier will provide the required gain (more is usually OK since inside of individual receivers you typically

have a gain control in the IF you can turn down). We **also** need to know that the amplifier is capable of handling the 'output power' our system will create. Output power?

Say the amplifier you select has 23 dB of gain. Exactly. But, it has another specification as well; 'Maximum output capability/ +30 dBmV'. Let's see, if we start with +10 dBmV and we have 23 dB of gain, that's a total output of +10 and 23 or **+33** dBmV. Ooops. That is 3 dB more than the manufacturer rates the amplifier for. Is that bad?

It is, because when an amplifier's input signal (+10 dBmV in our example; it could be higher of course) plus the gain of the amplifier adds up to a new number which is **greater than** the output capability specified, the amplifier adds distortion to the signals. They no longer are amplified properly and they become distorted in the amplifier. This is why you cannot stick an unlimited number of 23 dB gain amplifiers in 'series' (i.e. one right after the other) to get a 'super output level'; at some point the input of one plus the gain of the amplifier will add up to some number greater than the output capability of the amplifier (transistors). Not good. And something to be mindful of.

Of course the amplifier should be 75 ohm, with appropriate coaxial

cable fittings (300 ohm home-style amplifiers are to be avoided!). And, the amplifer **must cover** the intended frequency range of the system; such as 440 to 940 MHz. It would also be nice if the amplifier was capable of being cable powered by the power supply in your receiver (right voltage, little enough current that the receiver can handle the new, extra load) and it has a manual 'gain control'. There is nothing to be gained by operating the amplifier at more gain than your system requires; if your layout calls for a 20 dB amplifier and the one you select has 23 dB of gain, it would be best to be able to turn down the gain 3 dB to the 20 dB required; just to keep everything operating as it should. And it would be nice if the amplifier had a 'tilt' control.

TILT?

That may be a new term to you.

Remember that our cable losses vary with frequency; more or greater cable losses at higher frequencies. However, our splitter losses are independent of frequency; if the two-way splitter has 4 dB of 'split-loss' at 440 MHz, it should be expected to have 4 dB of 'split-loss' at 940 MHz too. That means we really have two types of loss at work here and we'll study that sub-problem shortly.

We ran through our example system by adding up the losses for the longest cable (plus splitter loss) 'legs' in the miniature distribution system example originally given. We also took the 'worst cases losses' for our cable portion, and those were the losses at the highest frequency part of the BDC 'IF' band. Our example used a 440-940 MHz IF, which is similar to those for **Anderson, Janeil, Locom** and **TX Engineering** 'low cost' BDC equipment. The loss figure we used in our calculations, for the cable, was 7.0 dB per 100 feet **at 940 MHz** (RG-6 type cable).

But the loss **at 440 MHz,** in the same 100 feet of cable, is **4.6 dB;** not 7.0 dB. How do we handle that? Do we worry about the difference?

In a short run system, or in a short system where there is as much or more splitter loss as cable loss, worrying about the 'difference' between loss at the high end of the IF range and loss at the low end may not be worth the time and trouble. If you can end up at your worst-case receiver with no more than 3 dB of difference between the high end (greatest loss) signal and the low end (lowest loss) signal, forget about it. But as you use more and more cable and the difference between the two extremes becomes greater than 3 dB, pay attention to 'equalizing cable tilt'.

Some amplifiers have a 'tilt control'. That means they rate themselves

for the amximum gain at the highest frequency (such as 23 dB gain at 940 MHz). Then they provide a control, adjustable by the installer, which changes the gain towards the low(er) end of the band. **It lowers the gain for the low end** because **the cable loss is also lower there.** There is a 'tilt range' of so many dB and when you adjust that tilt control the gain at the high end stays fixed (stable) while the lower end portion reduces.

Some **'Cable losses vs Frequency'** are shown here for example cables. Note that the highest loss cable (RG-59/U) also has the greatest 'tilt difference'; 30 dB per 100 feet with the 9266 Belden cable used as an example. This is dangerously close to worrying about the tilt in a 100' plus system that only has a single receiver attached to the downconverter and antenna; a case to remember.

If you allow the tilt to 'take over' without 'equalizing' it, you will find that in a 'stretched system' the low end channels (TRs in the 1-7 or so region) look good while the higher end transponders (in the 17-24 region) don't look as good. That's because the cable losses are higher in the high frequency end, and there is simply less signal arriving at the (indoor) receiver at TR24 than there is at TR1.

In our **'Effects of Cable Tilt'** illustration, we see what happens in our earlier system example if we simply select an amplifier with 23 dB of gain (as required by our example) but with no 'tilt equalization' adjustment, or built-in (non-adjustable) tilt. In the top, we end up with a signal of **+12.75 dBmV** at receiver number **1A** (1B) while we end up with a signal of **0 dBmV** for receiver **2D**. That's at the highest frequency; 940 MHz. What about the same two locations, after the cable and splitter losses, at the low frequency end; 440 MHz?

If you compute the losses you find (as the bottom of the illustration depicts) that we have +16.95 dBmV of signal on TR1 for receiver 1A and +7.2 dBmV of signal for TR1 (440 MHz) at receiver 2D. Obviously these could be 'problem numbers' since we have exceeded the recommended 3 dB 'flat' difference.

A cable amplifier with tilt, on the other hand, can partially or totally correct this situation as shown in **'Cable Tilt Solution'** here. In the top, we have a graphic representation of the 'flat' 10 dBmV input signal from the downconverter (we assume the downconverter puts out +10 dBmV on all transponders; an 'ideal situation' seldom found in the real world). After the amplifier, the output signals are +33 dBmV, again 'flat' (i.e. not

tilted).

On the bottom of the illustration, we have the same process with a 'tilt equalizer' control on the amplifier. Now we have +10 dBmV input signal 'flat' across the input band and at the output we have a tilted gain output with +33 dBmV output at the **top** end (940 MHz/TR24) while at the low end the output has been 'tilt-reduced' to +25 dBmV. That is 8 dB of 'difference' and we would describe the system as haveing **'8 dB of tilt'**.

Return now to our 'Effects of Cable Tilt' example; at the receiver 1A/1B locations we had +12.75 dBmV on TR24 and +16.95 dBmV at TR1. By adding in the 8 dB of tilt, we will end up with +12.75 dBmV on TR24 and 8.95 dBmV on TR1. That's just under 4 dB of tilt difference.

However, in the receiver 2D location, we originally had +10 dBmV on TR24 and +7.2 dBmV on TR1. Now after the 8 dB of tilt we have 0 dBmV on TR24 and -0.8 dBmV on TR1. These are 'better' numbers but are they the best we can do?

Remember the tilt control is adjustable, by the installer. Given some way to know what is happening when the tilt control is adjusted (i.e. some method of measuring the effects of the change) we could find a 'happy medium' where with say 5 dB of tilt adjusted into the system we

would have:

1) Receivers 1A/1B: TR1 at +11.95 dBmV and TR24 at +12.75 dBmV;

2) Receiver 2D: TR1 at +2.2 dBmV and TR24 at 0 dBmV.

Now we have met the original goal of staying at 0 dBmV input signal level to each receiver on the system and also of staying within 3 dB of the same number with TR1 and 24 (extremes) levels into any receiver. Is the system ready to 'build'?

Almost.

Note that because we required the 23 dB of gain amplifier to make it to the 2D receiver location (and lesser amounts for closer receivers), we now have an abundance of signal at the closer receivers; numbers 1A and 1B. Is that +12 dBmV 'region' signal going to be a problem?

Most receivers ask for 0 dBmV (again, always check the manufacturer's specs or ask him if they are not printed in your manual). Most receivers, even in the low-cost BDC region, have internal (or external/rear-panel) 'IF Gain' controls. What you need to know is whether or not the 'range' of the gain control will handle the relatively 'hot' +12(.75) dBmV signal. If it will not, there is a quick fix; simply install an appropriate in-line pad (signal attenuator) with say 6 or 10 dB of 'pad value' at the **input** to the

top two-way splitter that divides the signal for receivers 1A and 1B. The pad needs to be frequency rated to the highest frequency you intend to use; be careful, many CATV pads don't work very well (if at all!) at 940 MHz. The effect is just like using a splitter that is only rated to say 500 MHz; the high end signals disappear into the noise while the low end signals look pretty good.

There is one more 'trick' that has saved many an installation; simply stick in 50 or 75 feet of extra cable on that leg, ahead of the top two-way splitter. The extra cable has loss (although tilted loss which will have to be adjusted for) and in effect it is a 'sort of pad' in this situation.